May 1960

75¢

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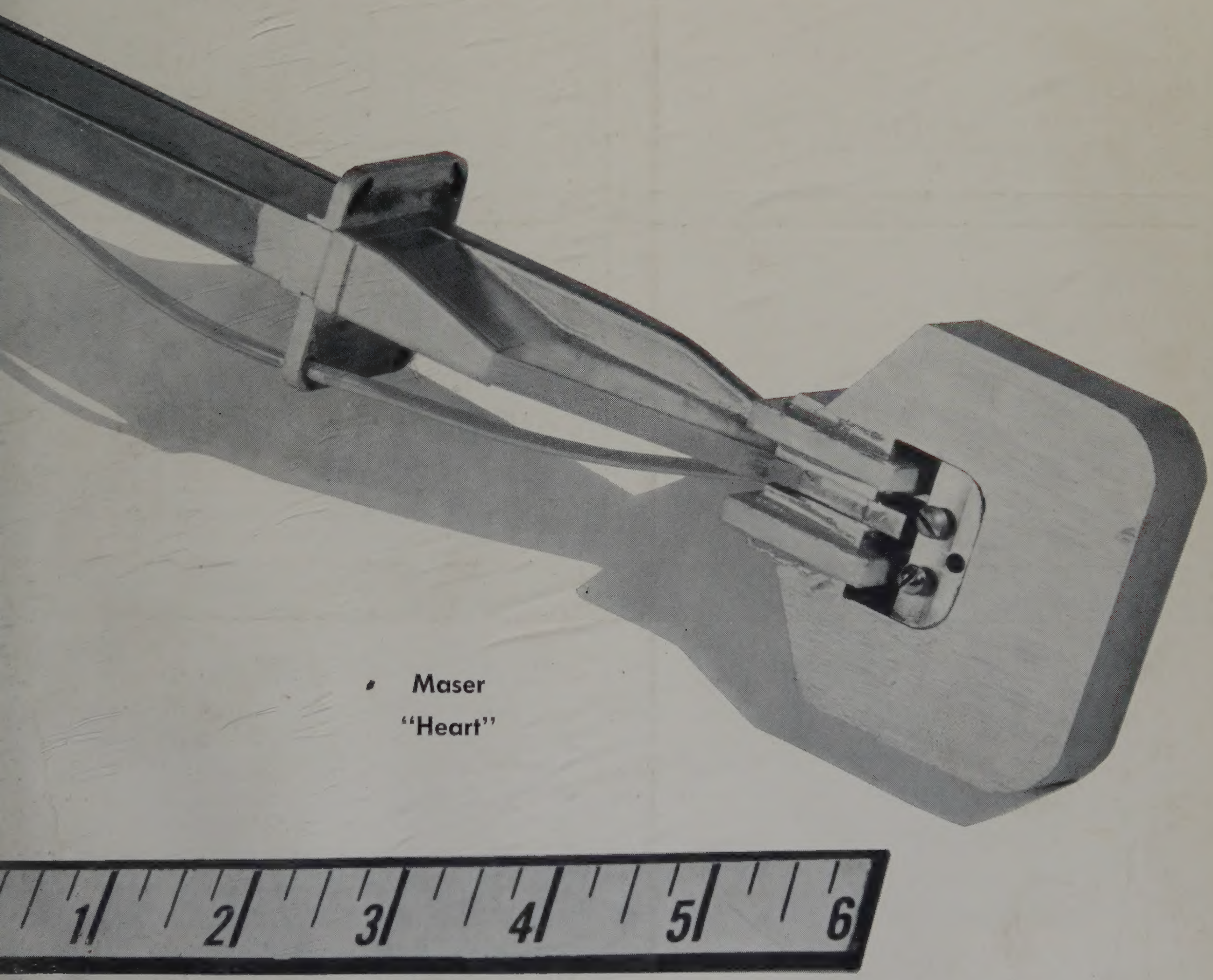

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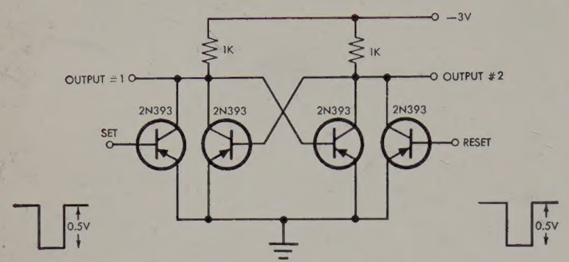
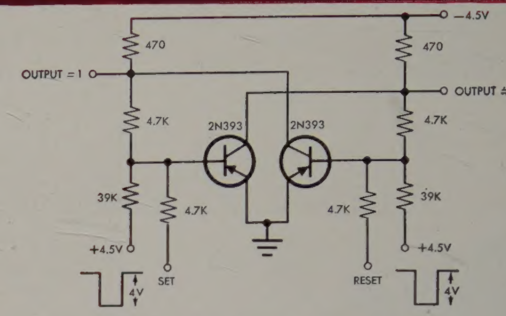
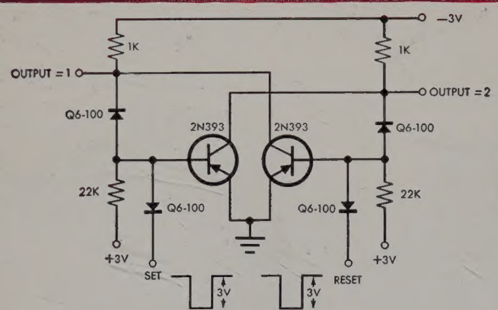


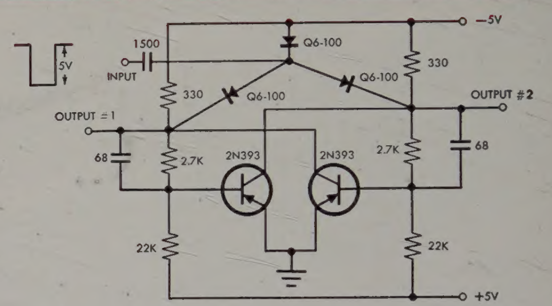
DIRECT COUPLED TRANSISTOR LOGIC FLIP-FLOP
TYPICAL SWITCHING TIMES: t_r=12 mμsec. t_f=15 mμsec.



RESISTOR COUPLED TRANSISTOR LOGIC FLIP-FLOP
TYPICAL SWITCHING TIMES: t_r=40 mμsec. t_f=110 mμsec.



DIODE COUPLED TRANSISTOR LOGIC FLIP-FLOP
TYPICAL SWITCHING TIMES: t_r=20 mμsec. t_f=60 mμsec.



RESISTOR CAPACITOR COUPLED TRANSISTOR LOGIC BINARY STAGE
TYPICAL SWITCHING TIMES: t_r=30 mμsec. t_f=44 mμsec.

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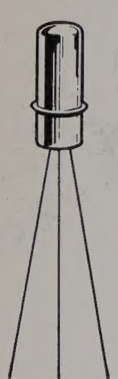

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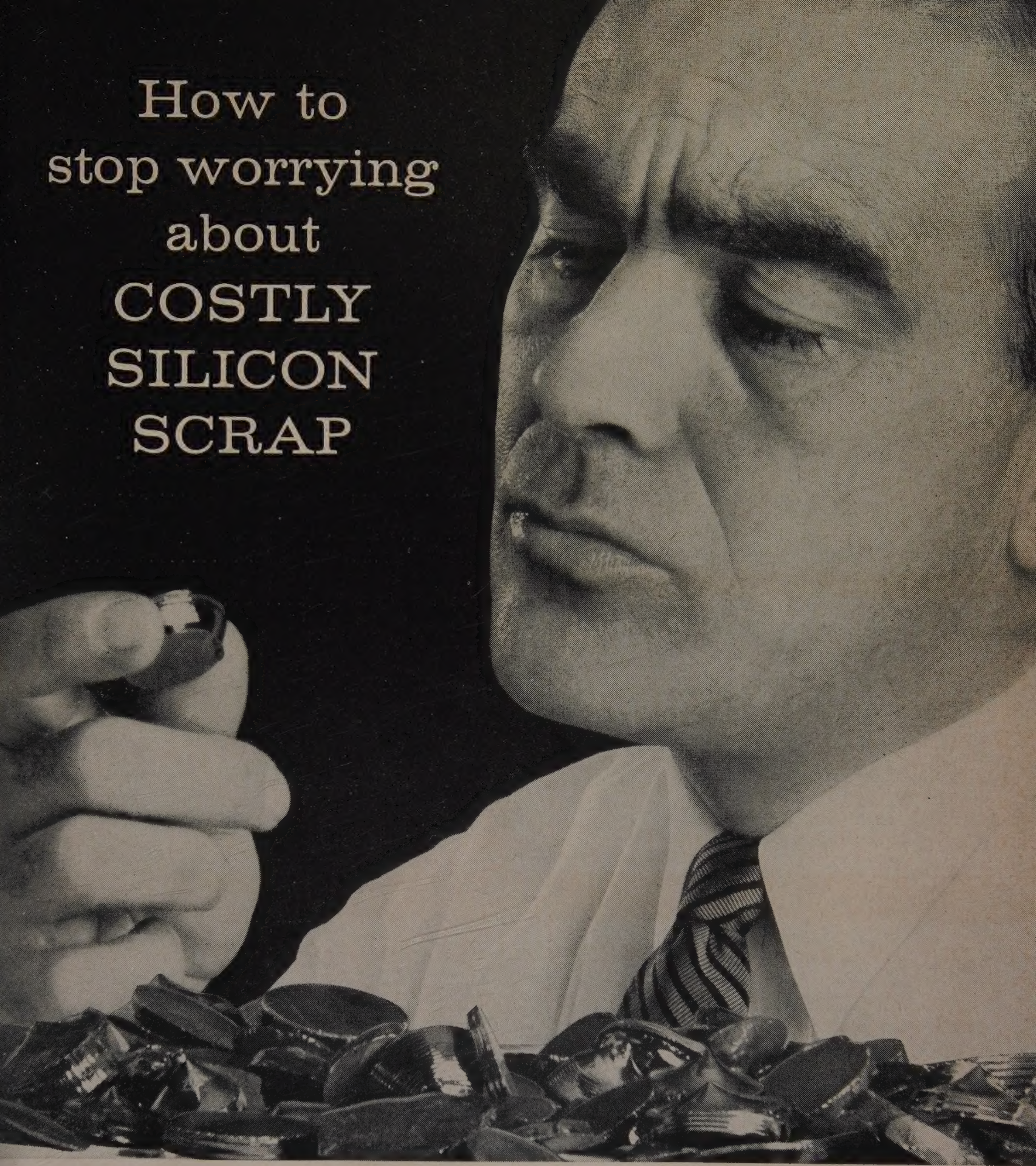

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

May 1960 Vol. 3 No. 5

CONTENTS

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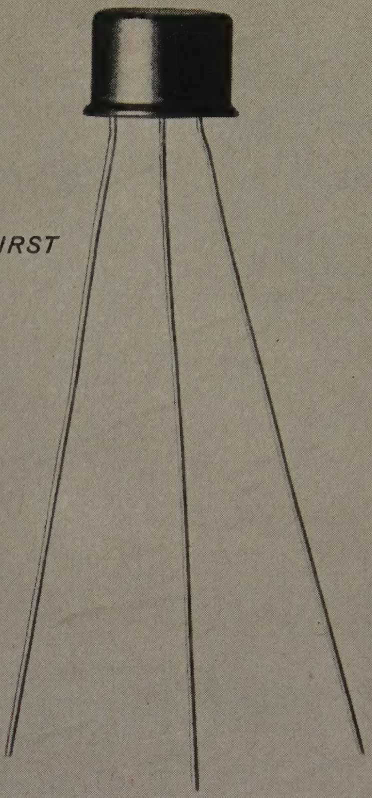
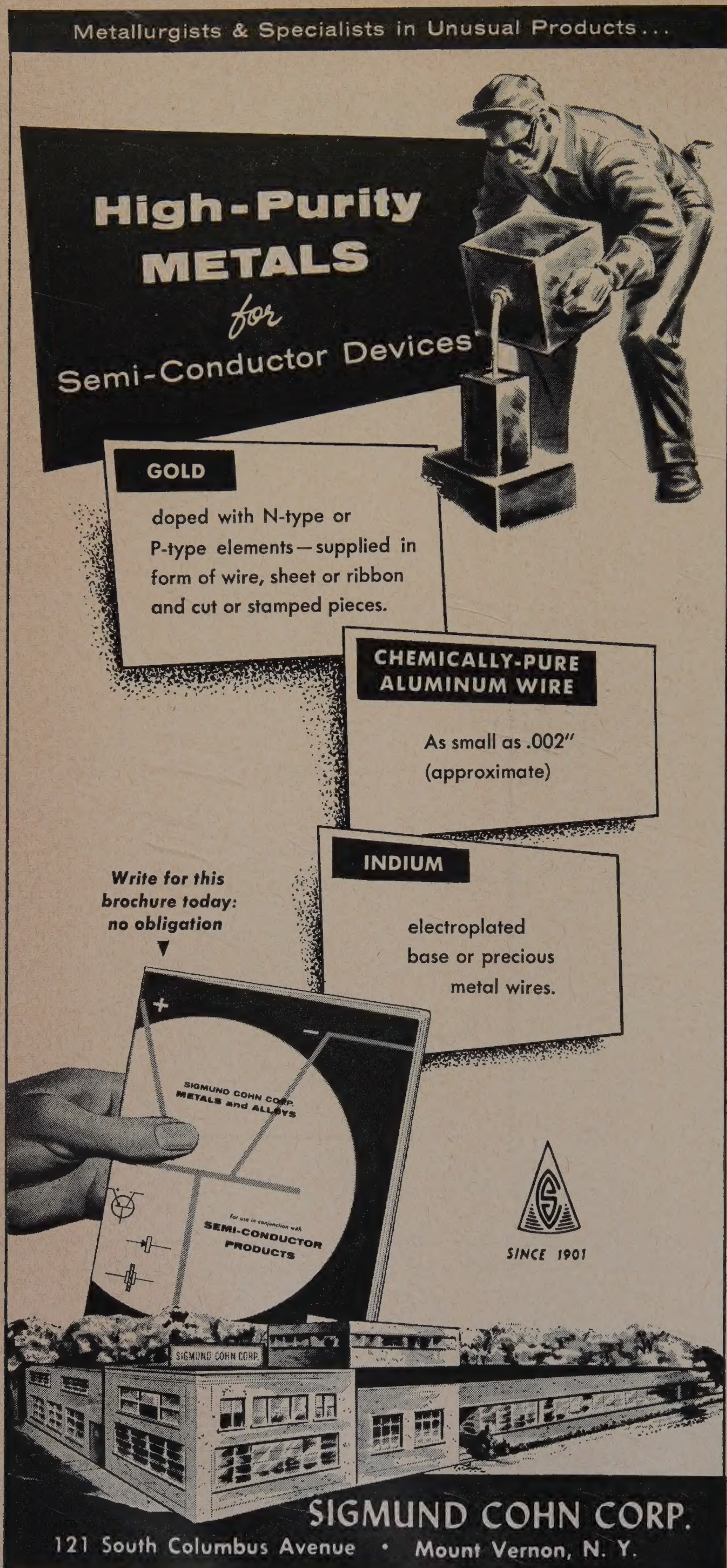
Front Cover

MASER "HEART"—Key to high performance of the unusual "ruby maser" developed by Hughes Aircraft Company lies in a six-inch area containing a gold-plated copper transition section, a half-inch square ruby crystal and a 12-ounce magnet. The magnet, at right, "tunes" the ruby so that it will operate at the correct frequency, which is determined by the strength of the magnetic field, and the angle between the crystal axis and the direction of the magnetic field. Darker section at left is the waveguide. The entire section is installed in a double-glass vacuum filled with liquid helium and nitrogen to supercool the ruby to a few degrees above absolute zero.





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SILICON NEWS from Dow Corning

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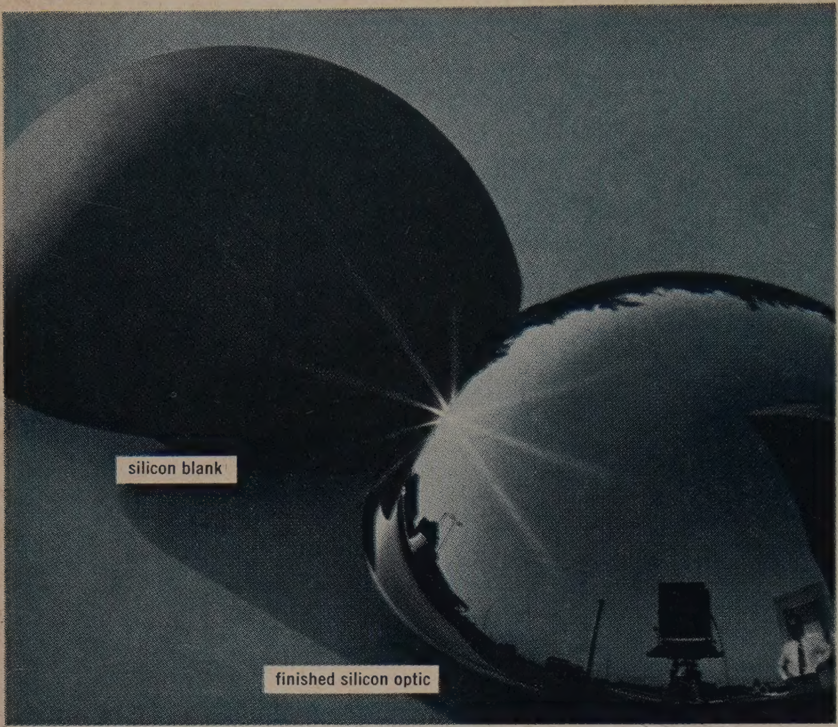

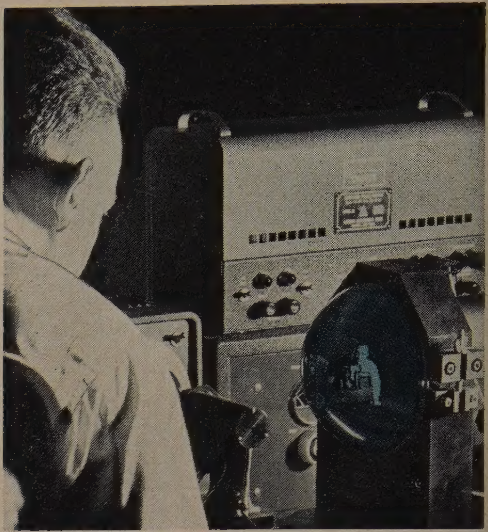

PHOTO COURTESY ACF ELECTRONICS DIVISION
ACF INDUSTRIES, INC.

Avion engineer "reflects" on Dow Corning silicon dome during test of infrared transmission characteristics. Avion's capability in infrared technology dates back to early research and development on the famous "Sidewinder" missile. Present interests and projects include airborne detection and tracking devices.

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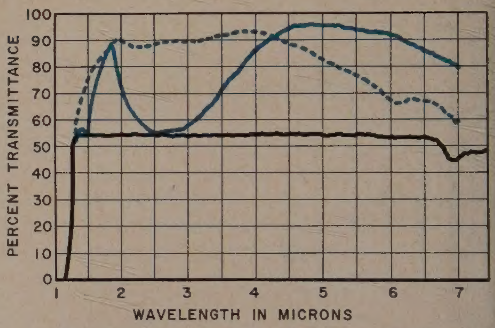

TRANSMISSION DATA COURTESY OPTICAL COATING LABORATORY, INC., SANTA ROSA, CALIFORNIA.

The black line indicates the percent of transmittance for silicon is relatively constant from 1.3 to 6.7 microns. Blue lines show how transmission is increased by coating. Single coating provides maximum transmission on a narrow band; several coatings, dotted blue line, give maximum transmission on a broad band.

Properties of Dow Corning Optical Silicon

Specific gravity	2.329 at 25 C
Melting point	1420 C
Hardness	7 Moh 1150 Knoop
Thermal conductivity	0.39 cal (cm sec. C°)
Thermal expansion	4.15 x 10^{-6}/C°
Specific heat	0.168 at 25°C
Dielectric constant	13 at 9.37 x 10^{9} cps
Elastic modulus (Youngs)	19 x 10^{6} psi
Flexural strength	20,000 psi

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SEMIMETALS, INC.

Book

TITLE: Masers

AUTHOR: J. R. Singer

PUBLISHER: John Wiley and Sons 1959

Masers is one of the first, if not the first, book describing the recently developed field of quantum amplifiers. The book comprises a unified approach to the topic not readily obtained from the many varied papers and published articles.

Chapters *I* and *II* comprise a simple understandable approach to the rather complex topic of quantum mechanics. The first chapter is a simplified description of the physical operation of the Maser and a historical review of developments. A complete bibliography at the end of the chapter refers the reader to the basic papers of the research workers. Chapter II is a mathematical treatment of the mechanics of the Maser; induced emission and absorbtion. The presentation starts with a discussion of a classical harmonic oscillator leading to considerations of energy interchange and finally absorbtion or induced emission as an outgrowth of the energy exchange polarity. The Einstein relationships and a discussion of amplification complete the chapters.

The third chapter deals with Gas Maser devices. The first quantum mechanical microwave oscillator, or ammonia "clock," is completely described here together with equations and relationships for power output, cavity design and random noise.

Chapter IV is a complete discussion of the phenomenon of electric paramagnetic resonance (EPR) of which the solid state maser is a special case. The classical description utilizing a rotating coordinate system may be found in section 4-3. The material presented considers the relaxation time, line breadth or band-width and overall quantum descriptions of the maser.

The balance of the book is devoted chiefly to a description of the two-level and three level amplifiers. The levels refer to the energy states that are useful in terms of the availability of "almost free" electrons. The processes of oscillation and amplification are treated and circuit diagram and typical equipment are discussed. The book closes with discussion of traveling wave masers. An excellent appendix derives various equations and compares masers and parametric amplifiers.

Masers is an excellent textbook for the serious microwave specialist. The material presented is well unified and clearly developed although a firm background in mathematics and physics, especially field theory is required for a thorough understanding. The early chapters however, give a good introduction to the Maser and should together with the rather complete bibliography aid in grasping the concepts.

Reviews

TITLE: Electronic Designers' Handbook

AUTHOR: Robert W. Landee
Donovan C. Davis
Albert P. Albrecht

PUBLISHER: McGraw-Hill

Electronic Designers' Handbook is an up-to-date collection of design data, equations, circuits and information to aid the circuit development engineer. The value of any book of this type lies in the presentation and accessibility of data. In this regard the handbook is excellent.

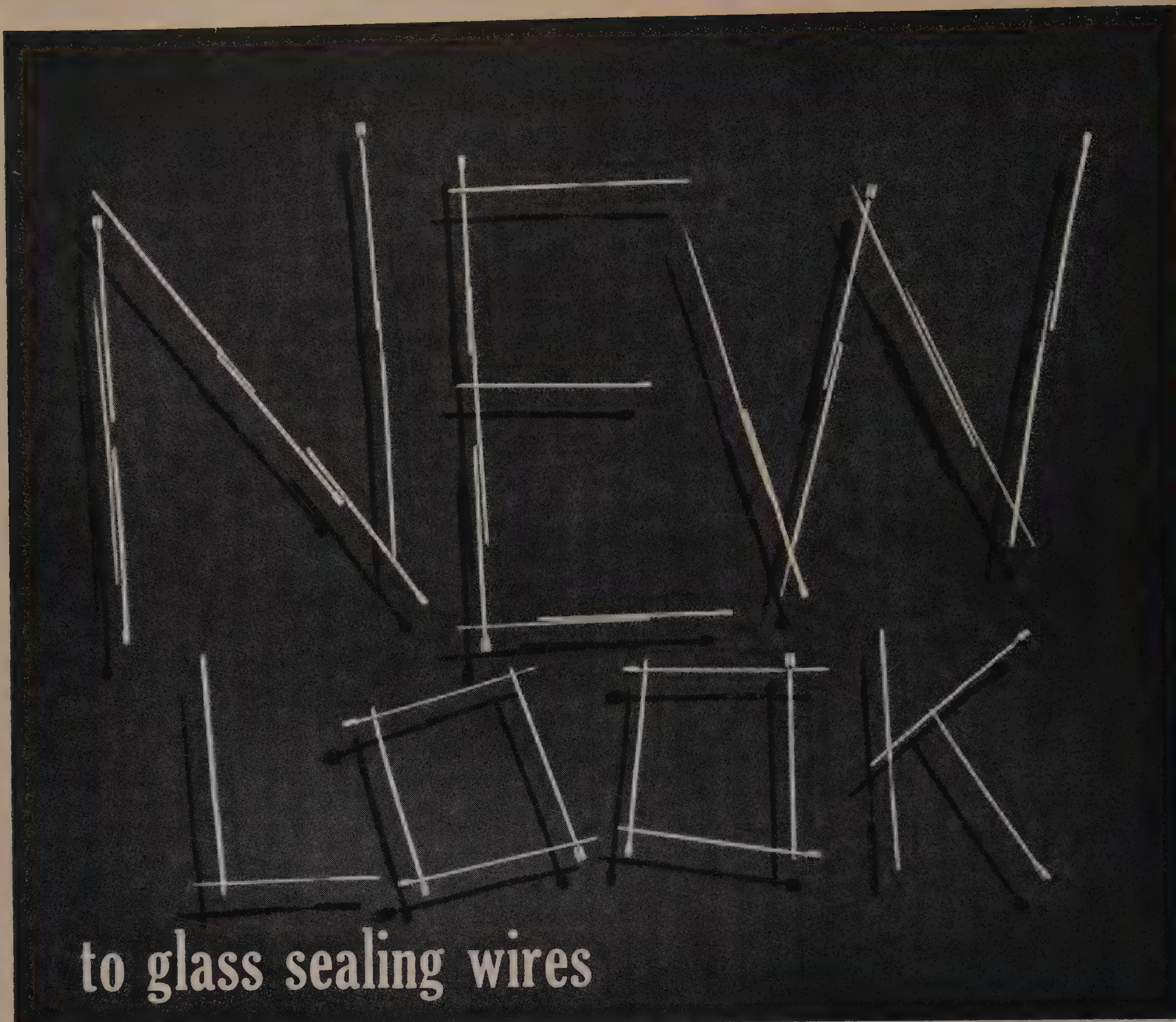
The material is presented in twenty three sections. The first section groupings (from Sections 1 to 7) cover a general range of basic topics such as tube amplifiers, oscillators, modulation and transistors. The seventh section is valuable for its system and noise concepts in receivers. The material is presented in a threefold manner: a technical discussion, circuit and parameter evaluation and an illustrative example. The practical examples worked out for the transistor circuits are particularly valuable in the understanding of temperature stabilization and overall gain.

A substantial portion of the book is devoted to pulse and pulse handling circuits. There are sections on multivibrators, sawtooth generators, trigger circuits, clippers, limiters and clamps. A limitation here is the lack of presentation of transistor circuitry for pulse work, however the vacuum tube considerations are excellent.

The balance of the handbook deals with electronic topics. The design of power supplies and iron core components are covered in Sections 14 and 15. Attenuators, equalizers and filters are discussed in the following two sections. An excellent treat ent of principles of analogue computers and servomechanisms may be found in Section 19. The concluding chapters cover networks waveform analysis, and antennas.

The *Electronic Designers Handbook* is concise, accurate and well written. The clarity of description and the numerous illustrative examples serve to enhance the work and increase the usefulness of this book.

By Stephen E. Lipsky



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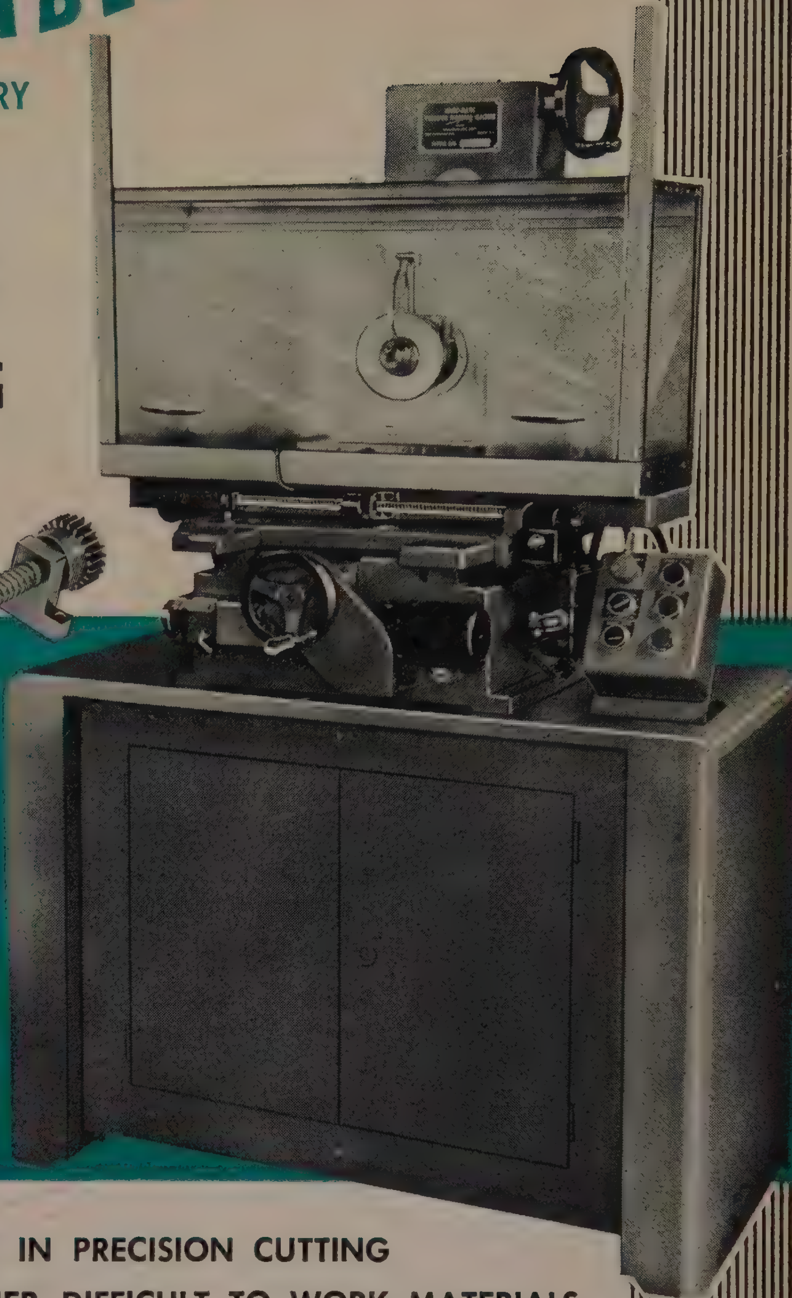

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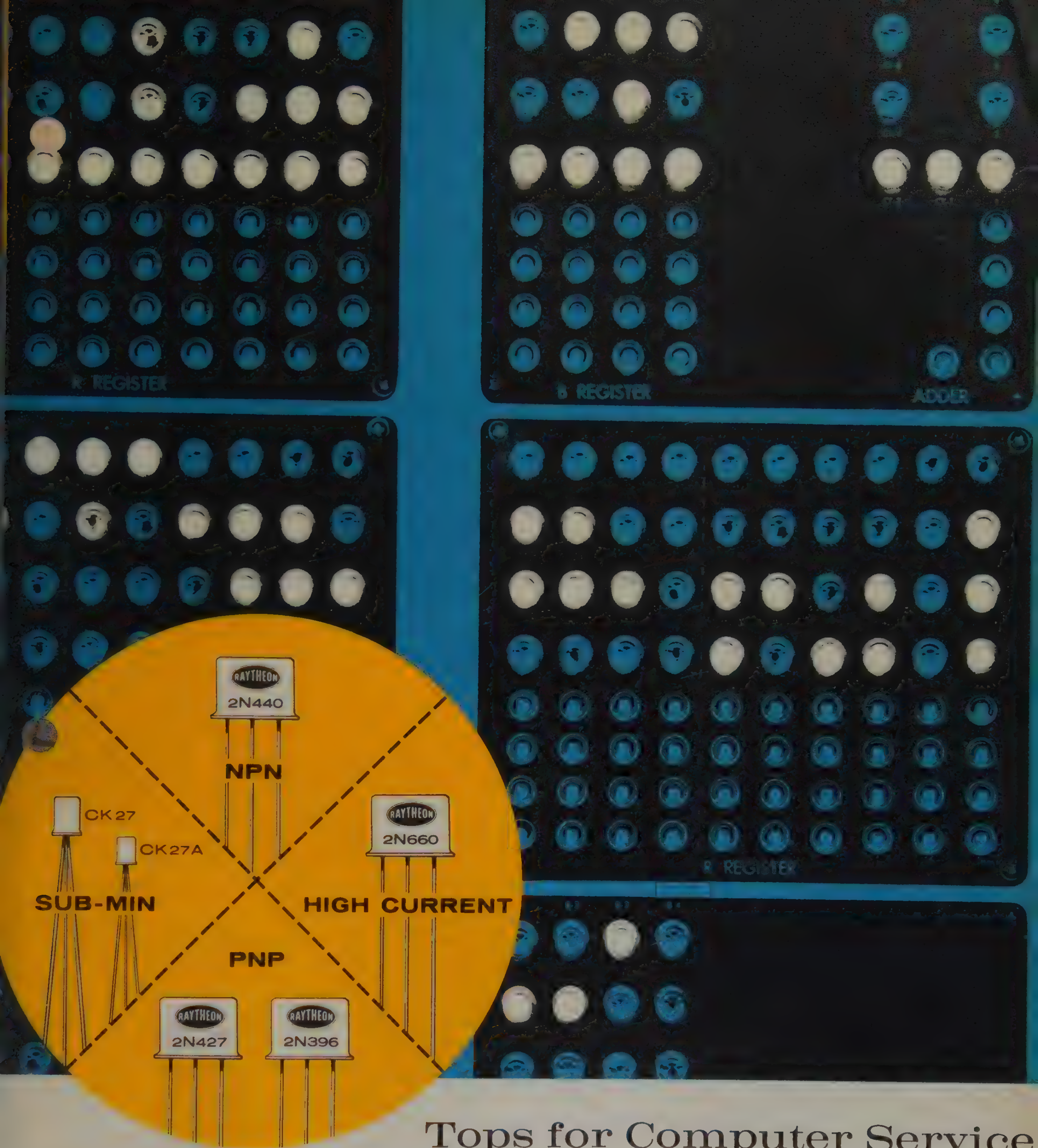

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Type	B_{VPT} Max. Volts	f α b mc	H_{FE1}	H_{FE2}	R_{sat} ohms
2N395	15	4.5	40	12	2.2
2N396	20	8.0	60	20	1.3
2N397	15	12.0	80	35	1.1

A COMPLETE HIGH CURRENT SWITCHING LINE PNP germanium switches for 1 amp, high frequency, high gain service. Temperature range −65°C. to + 85°C. Long a production item—excellent availability in large volume.

Type	B_{VPT} Max. Volts	f α b ave. mc	H_{FE1} ave. $I_B = 1mA$ $V_{CB} = -0.25V$	H_{FE2} ave. $I_B = 10mA$ $V_{CE} = -0.35V$	$I_C = 150mA$ ohms
2N658	−16	5	50	40	0.9
2N659	−14	10	70	55	0.6
2N660	−11	15	90	65	0.45
2N661	− 9	20	120	75	0.35
2N662	−11	8	30 min.	50	0.7

IMPROVED DISSIPATION AT LOWER CURRENT VALUES NPN germanium transistors for medium current, high frequency, high gain switching service. Temperature range −65°C. to +85°C. Immediate availability.

Type	B_{VPT} Max. Volts	f α b mc	H_{FE1}	R_{sat} ohms
2N438	25	2.5	25	3.0
2N439	20	5.0	45	3.0
2N440	15	10.0	70	3.0

HIGH RELIABILITY PNP TRANSISTORS germanium transistors for medium current, high frequency switching service. Temperature range −65°C. to +85°C. Immediate availability.

Type	B_{VPT} Max. Volts	f α b mc	H_{FE1}	H_{FE2}	R_{sat} ohms
2N425*	−30	4	30	15	2.2
2N426*	−25	6	40	18	2.2
2N427*	−20	11	55	20	1.3
2N428*	−15	17	80	30	1.1
2N404*	−24	12		See Data Sheet	

* Available to MIL Specification

SUB-MINIATURE TRANSISTORS Sub-miniature transistors for medium current, high frequency, high gain switching. Temperature range −65°C. to +85°C. Immediate availability.

TYPE .130″ Dia. x .160″ High	TYPE .100″ Dia. x .130″ High	B_{VPT} Max. Volts	f α b mc	H_{FE1}	H_{FE2}	R_{sat} ohms
CK 25	CK 25A	−30	4	30	15	2.2
CK 26	CK 26A	−25	6	40	18	2.2
CK 27	CK 27A	−20	11	55	20	1.2
CK 29	CK 28A	−15	17	80	30	1.1

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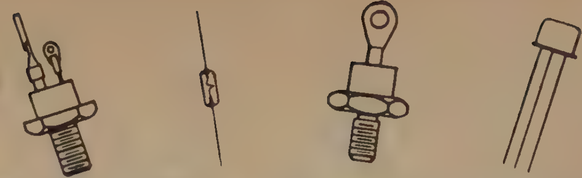

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- *optimum insulation for stability.*
- *provisions to increase the number of controls for specific results.*

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Two Zone Furnace adjustable 25° up or down from horizontal
Single Tube: 2 Zones 2¼″ I.D., approx. 72″ long
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Maximum Temperature:
Zone 1: 0° to 1000° ±1°C
Zone 2: 800° to 1400°C
Tolerance: ±2°C for 1300° Operation
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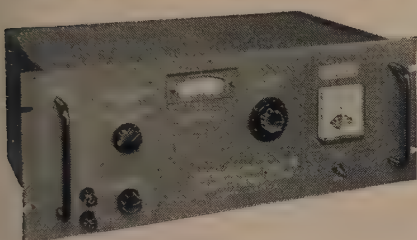

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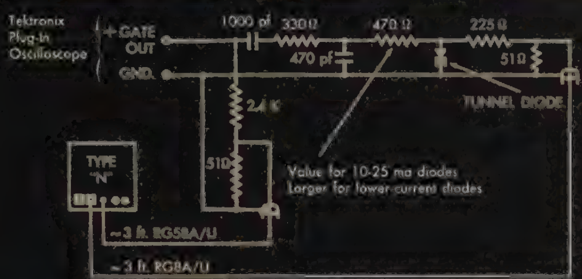

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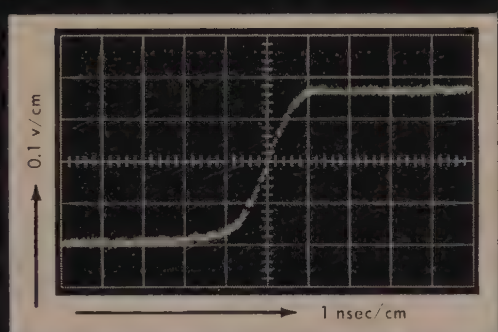

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Editorial . . .

Traveling Wave Parametric Amplifiers

The advantages of traveling wave structures, such as transmission lines or waveguides periodically loaded with parametric diodes, over structures with only one parametric diode, have been pointed out repeatedly in the literature. These consist of wide-band, non-critical large-gain, low-noise, limited reverse-gain even in the absence of a circulator. A useful contribution to the design of such amplifiers has recently appeared in the literature (*C. V. Bell* and *G. Wade—Trans. IRE-CT, March 1960*). In this work an infinite transmission line is considered, which is periodically loaded with the diodes. Assuming that modes of propagation exist at the signal and idler frequencies, the corresponding traveling waves must have a periodicity which is determined by the diode separation. If L is such separation, β_o is the phase characteristic of the unloaded line, and $G + jB$ is the equivalent admittance of the diode at the frequency in consideration, the phase shift β_L and the gain of each traveling wave per diode section αL are expressed as follows:

$$\cos \beta L = \cos \beta_o L - (B/2) \sin \beta_o L$$

$$\alpha L = G \sin \beta_o L / (2 \sin \beta L)$$

The first relation is useful for the determination of the operating conditions and the second one for the computation of the power gain. In fact, in order to assure that the signal and the idler frequencies are in the pass band, their corresponding phases ϕ_s and ϕ_i must satisfy the condition $\phi_s + \phi_i = 2\,m\pi$ where $m = 0, 1, 2, 3, \ldots$ This is equivalent to the condition that the corresponding group velocities are equal.

For large band operation the condition must be satisfied throughout the desired frequency range. This is determined graphically, plotting phase shift per section β_L versus normalized frequency for the given transmission line. In particular, a convenient solution is obtained selecting a bandwidth symmetrical with respect to the degeneracy point (where $\omega_s = \omega_i$). The condition requires, of course, that the pump frequency be selected appropriately so that gain occurs at degeneracy. The same graph is useful to check that the sidebands $\omega_s + \omega_p$ and $\omega_i + \omega_p$ are in stop bands, since the above frequencies, if in propagating mode, would produce a decrease of the magnitude of the negative conductance of the diodes and therefore a decrease in gain. Finally the same graph is used to assure limitation of the gain in the reverse direction, imposing a condition on the phase shift per section at the pump frequency.

The gain per section is found to be the same for the signal and the idler frequency and is expressible in terms of the amplitude of the variation of the capacitance, of the geometric mean of ω_s and ω_i, and of the characteristics of the transmission line.

Semiconductor Circuit Design Awards

The Semiconductor Circuit Design Contest entries for the most outstanding Semiconductor Circuit Design Article, and for the most outstanding Nomograph related to Semiconductor Circuit Design which appeared in SEMICONDUCTOR PRODUCTS between April 1959 and March 1960 are now being evaluated by the Judges. As soon as a decision is reached appropriate announcements will be made.

New Semiconductor Device Charts

In the near future our Semiconductor Device Characteristics Charts will be expanded to include all semiconductor devices. Examples of these are electroluminescent devices, detectors, thermoelectric generators, thermistors, molecular electronic devices, and semiconductor devices that lend themselves to ferroelectric and maser applications. Manufacturers of such devices are urged to submit product parameter information for publication in our Charts.

Samuel L. Marshall

Esaki or Tunnel Diodes

WOLFGANG W. GÄRTNER*

Part 1

This survey article discusses the physical effects which produce the electrical characteristics of the tunnel diode, outlines design and construction of the devices, describes the electrical properties realized thus far, gives diagrams and design equations for *d-c* bias, oscillator, amplifier and switching circuits, and analyzes in general the potentialities of the new device.

1. Introduction

In October 1957, Leo Esaki,[a] research physicist at the Tokyo Tsushin, Kogyo, Limited,[b] Tokyo, Japan, submitted a one-page "Letter to the Editor" of the *Physical Review*[1] describing and explaining the current-voltage characteristic of a very narrow *p-n* junction in germanium which exhibits a negative differential resistance over a certain range of applied bias. This device has since become known as the "Esaki" or "Tunnel" diode[c] and several million dollars have been spent on its civilian and military development in the United States. Commercial availability was first announced by the General Electric Company and many other companies have followed suit. Frequent news releases in recent months have sparked widespread interest in the device. In this article, we shall describe the effect from the phenomenological and the theoretical points of view, consider the design and construction of the Esaki diode, discuss the performance of present units and summarize the basic proposed applications.

2. The Effect

The diode consists of an abrupt *p-n* junction between two very highly doped regions. The total thickness of the transition region is of the order of 100 Å = 10^{-6} cm. A typical *d-c* characteristic of such a diode built in germanium is shown by the solid line in *Fig. 1*. The dashed line labeled "diffusion minus drift" indicates, for comparison, the characteristic of an ordinary *p-n* junction rectifier of identical geometry but with higher resistivities in the *p* and *n* regions than those in the Esaki diode. The striking features of the tunnel diode are:

a. its high reverse current, higher than the regular forward current;

b. a rapid increase in forward current at very small forward voltages, followed by a drop producing a region of differential negative resistance. At still higher voltages, the current increases again and the characteristic becomes identical with that of an ordinary *p-n* junction diode.

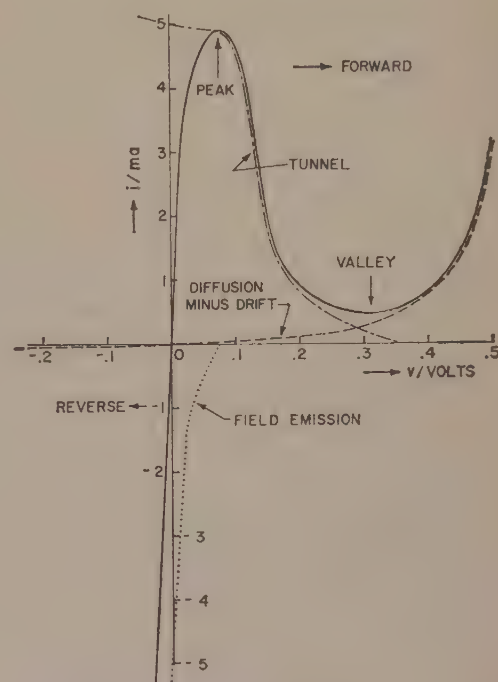


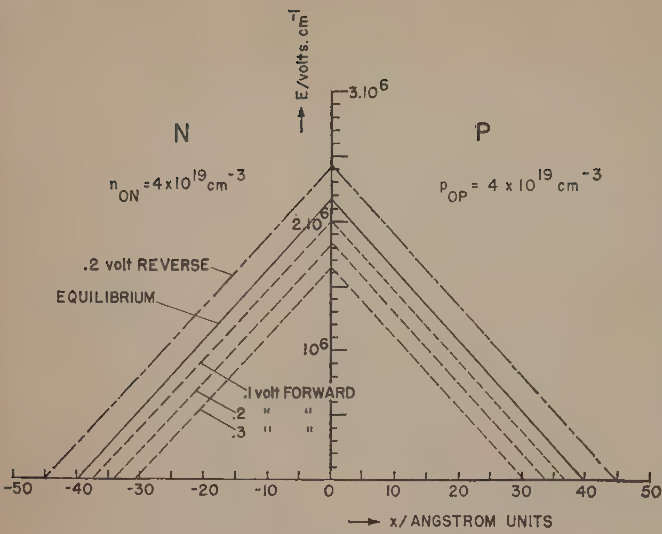
Fig. 1—Typical tunnel diode characteristic in germanium, showing contributions from the four active mechanisms.

The voltages at the peak and valley points of the current do not vary much between diodes made of the same semiconductor. The actual values of the currents, however, may differ by orders of magnitude depending on the design—primarily the junction area (see below).

For active applications, the negative-resistance region is, of course, of primary importance. For the theoretical interpretation of the underlying mechanisms, however, a knowledge of which is required for

*Chief Scientist, Solid State Devices Division, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey.

(a) Dr. Esaki is presently resident consultant to the IBM Laboratories in Poughkeepsie, New York.
(b) Now known as Sony Corporation.
(c) We shall use both terms interchangeably.



$$|x_P| = \left[\frac{2\varepsilon}{q} |V_{EQ} + V_{AP}| \frac{n_{ON}}{P_{OP}(n_{ON} + P_{OP})} \right]^{1/2}$$

$$|x_N| = \left[\frac{2\varepsilon}{q} |V_{EQ} + V_{AP}| \frac{P_{OP}}{n_{ON}(n_{ON} + P_{OP})} \right]^{1/2}$$

$$|x_P| + |x_N| = \left[\frac{2\varepsilon}{q} |V_{EQ} + V_{AP}| \frac{n_{ON} + P_{OP}}{n_{ON} P_{OP}} \right]^{1/2}$$

$$V_{EQ} = (kT/q) \ln (P_{ON}/P_{OP})$$

$$|E_{max}| = \frac{q}{\varepsilon} n_{ON} |x_N|$$

$\varepsilon_{Ge} = 1.41664 \times 10^{-10}$ FARAD. m^{-1} in Ge

$q = 1.6 \times 10^{-19}$ COULOMB

Fig. 2—Electric-field distribution in an abrupt *p-n* junction with a majority-carrier concentration of 4×10^{19} cm^{-3} on both sides, for various values of applied forward and reverse voltages, v_{AP}

the formulation of a design theory, we shall consider the entire characteristic.

3. Mechanism

Four different carrier-transport phenomena superimpose to produce the observed I/V characteristic.

The first two of these are the electron and hole diffusion (forward direction) and drift currents (reverse direction) in the junction which cancel almost completely over a wide range of forward and reverse bias voltages. The slight disturbance of this perfect balance between the two types of current by an applied voltage produces the usual rectifier characteristic of the *p-n* junction (dashed line in *Fig. 1*).

From *Fig. 1* one observes that the two phenomena considered thus far account for only the high-forward bias portion of the characteristic.

An indication of the additional effects present is obtained by calculating the bias-voltage dependence of the electric field distribution in the junction and in particular the maximum field strength in the depletion layer. For an abrupt junction, *Fig. 2* shows the results for various bias voltages. One notices that the electric field in the junction is enough to produce (a) avalanche multiplication,[2] and (b) internal field emission.[3] By carrying out a careful analysis like the one given by Chynoweth and McKay,[4] one concludes that avalanche multiplication requires a certain minimum reverse voltage (a few volts) and does not take place in the immediate vicinity of the origin of the characteristics. Internal field emission, however, does occur. This third effect to contribute to the I/V characteristic of the tunnel diode consists of the excitation of a valence electron into the conduction band under the influence of a high *d-c* electric field. Several attempts have been made[5] to estimate the probability of this transition, and it has been found to be approximately equal to

$$P = \frac{\text{number of transitions}}{(\text{unit time}) \cdot (\text{volume in which } E \text{ prevails})} \tag{1}$$

$$= (NaqE/h) \exp \left[- \frac{\pi^2 \sqrt{2m_{eff}}}{2hq} \frac{(E_G)^{3/2}}{E} \right]$$

where

N is the density of valence electrons,
a is the lattice constant,
E is the electric field strength,
h is Planck's constant $= 6.62 \times 10^{-34}$ joule.sec (MKS),
q is the electronic charge $= 1.6 \times 10^{-19}$ coul. (MKS),
m_{eff} is the effective mass of the electron, and
E_G is the width of the band gap.

Substituting the following values for germanium: $N = 1.8 \times 10^{29}\ m^{-3}$; $a = 5.7 \times 10^{-10}$ m; $m_{eff} = 9.11 \times 10^{-31}$ kg; $E_G = .67\ ev = 1.07 \times 10^{-19}$ watt-sec; we find

$$P = 2.484 \times 10^{34} \times E \times \exp(-2.2018 \times 10^9/E). \tag{2}$$

This function is shown in Table I for electric field values which are of interest in this problem. If a high electric field, E, prevails over a distance, d, the field-emission current through a cross-sectional area, A,

TABLE I

Number of band-to-band transitions (due to field emission) per second, P, in a given volume (in m^3) of germanium in which a field, E (in volts.m^{-1}), prevails.

Electric field, E, in volts . m^{-1}	Number of transitions, P, in sec^{-1} . m^{-3}
1×10^7	5.91×10^{-55}
2×10^7	7.67×10^{-7}
3×10^7	9.95×10^9
4×10^7	1.23×10^{18}
5×10^7	9.32×10^{22}
6×10^7	1.72×10^{26}
7×10^7	3.80×10^{28}
8×10^7	2.21×10^{30}
9×10^7	5.30×10^{31}
1×10^8	6.80×10^{32}
5×10^8	1.51×10^{41}
1×10^9	2.74×10^{43}

perpendicular to the direction of the electric field is given by

$$i = qAdP \qquad (3)$$

An electric field of 10^6 volt.cm^{-1} active over a distance of 100 angstroms e.g., generates a field-emission current density in germanium at room temperature of approximately 109 amps.cm^{-2}. If the electric field E, and therefore P are functions of x (as in all junctions), one must replace this expression by

$$i = Aq\int P\,dx \qquad (4)$$

When the electric-field distribution across the junction has been determined by the methods outlined in connection with *Fig. 2,* one may evaluate this integral and obtain the field emission current for given impurity distribution across the junction (in particular e.g., for graded junctions as they are frequently obtained experimentally).

From *Fig. 2,* one observes that in these narrow junctions the electric field strength even under thermal equilibrium conditions is high enough to produce internal field emission, although in general the field-emission current is much smaller than the balanced drift and diffusion currents in the junction (which in these narrow junctions lie in the order of 10^6 to 10^7 amps.cm^{-2}). The striking feature of the field-emission current is its extreme sensitivity to changes in the electric field (see Table I).

As the maximum electric field in the depletion layer is given by

$$\left| E_{MAX} \right| = \left[\frac{2q}{\epsilon} \left| v_{EQ} + v_{AP} \right| \frac{n_{ON}p_{OP}}{(n_{ON} + p_{OP})} \right]^{\frac{1}{2}} \qquad (5)$$

one observes that this field and, therefore, the field emission current under thermal equilibrium conditions, increases rapidly with increased impurity content on either side of the junction. Since the field also depends on the applied voltage as demonstrated in *Fig. 2,* it is obvious that this current will increase rapidly with reverse bias and vanish rapidly under forward bias. It has been plotted as a dotted line in *Fig. 1,* and is seen to account very well for the high reverse current of the tunnel diode.

The initial high forward current and the negative-resistance region, however, have not yet been explained. This portion of the characteristic requires an electron current from the n to the p side or a hole current from the p to the n side, which are high at small forward biases (most likely present under thermal equilibrium) and which drop off as the forward bias is increased. Such a current is provided by the fourth effect present in the Esaki diode, namely "tunneling."

Fig. 3 illustrates the basic principle of the quantum-mechanical "tunnel" effect: According to classical mechanics, when a particle with a total energy, E, approaches a potential barrier of height, U_0, and width, w, from the left, it will either pass the barrier if its energy is higher than the barrier ($E > U_o$), or it will

TABLE II

List of Symbols Not Defined in the Text

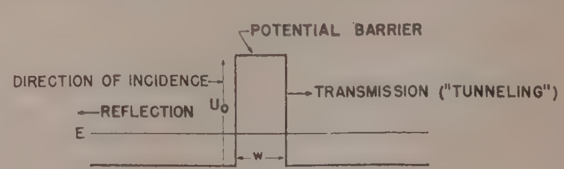
E_{max}:	maximum electric field strength inside junction depletion layer
k:	Boltzmann constant
n_{ON}:	equilibrium electron density on n side
p_{OP}:	equilibrium hole density on p side
T:	absolute temperature
v_{AP}:	applied voltage
v_{EQ}:	equilibrium potential difference across junction
v_{th}:	average thermal velocity of electrons
x_N:	extension of the junction depletion layer into the n side
x_P:	extension of the junction depletion layer into the p side
ε:	dielectric constant

be reflected by the barrier if its energy is lower, ($E < U_o$). It is one of the important results of quantum mechanics, however, that even if the particle energy is lower than the height of the potential barrier, there is a certain probability that the particle penetrates the barrier, provided the latter is sufficiently thin and not too high. The tunneling probability is given in *Fig. 3.*[6] For $U_o - E = 1$ *ev* and m equal to the electron mass we find:

"tunneling" probability $\simeq 16[E/U_o - (E/U_o)^2] \exp(-w \times 8.39 \times 10^7)$

where w is to be measured in cm. It is seen to increase exponentially with decreasing barrier width, w, and decreasing $(U_o - E)^{1/2}$.

The potential barrier in the case of the tunnel diode is given by the electrostatic potential difference, $v = v_{EQ} + v_{AP}$, between the n and the p sides of the junction. (This is clearly seen if one considers that an electron must acquire an energy equal to qv if it wants to travel from the bottom of the conduction band on the n side to the bottom of the conduction band on the p side.) Under thermal equilibrium conditions, the Fermi level, E_F, is a constant throughout the crystal and the corresponding band picture is shown in *Fig. 4a.* The carrier densities are approximated by $n_O = N_C \exp - (E_C - E_F)/kT$ and $p_O = N_V \exp - (E_F - E_V)/kT$ where N_C and N_V are the "effective" densities of



TUNNELING PROBABILITY $= \left\{ 1 + \left[4\left(\frac{E}{U_0} - \frac{E^2}{U_0^2} \right) \right]^{-1} \sinh^2 \left[w\sqrt{2m(U_0 - E)}/\hbar \right] \right\}^{-1}$

Fig. 3—Fundamentals of the tunnel effect.

states in the conduction and valence bands respectively and are given approximately by 2.5×10^{19} $(m_{eff}/m)^{3/2}$ cm^{-3} in germanium at room temperature. From these equations one may estimate the position of the Fermi level, E_F, and for $n_{ON} = 4 \times 10^{19}$ cm^{-3} one finds the Fermi level 0.07*ev* inside the conduction band. When a bias is applied (*Figs. 4b* and *4c*) the quasi-Fermi levels for electrons on the n side, ϕ_n, and for holes on the p side, ϕ_p, retain their relative positions with respect to the band edges, but they differ by the magnitude of the applied voltage, and the energy-band scheme adjusts accordingly. One observes that for high doping where the Fermi level lies inside the bands, the upper edge of the valence band on the p side, E_{VP}, lies higher than the lower edge of the conduction band on the n side, E_{CN}, under equilibrium, reverse bias and very small forward bias. This means that between E_{CN} and E_{VP} there is a range of permissible levels with equal energies on both sides of the junction and separated by a barrier whose height is approximately equal to the band gap and whose width is approximately equal to the width of the junction depletion layer, $|x_N| + |x_P|$.

Approximately $n_{ON}v_{th}/6$ electrons strike 1 cm^2 of

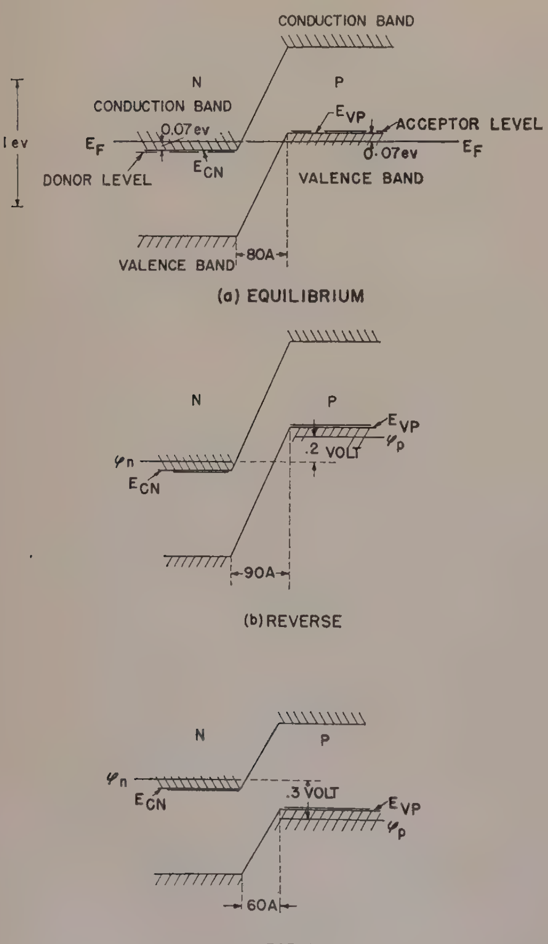


Fig. 4—Energy-band diagram in germanium tunnel diode with an impurity content of 4 x 10^{19} cm^{-3} on both sides of the junction. (A) Thermal equilibrium. (B) 0.2 volts reverse voltage. (C) 0.3 volts forward voltage.

this barrier per second ($\approx 10^{27}$ cm^{-2} sec^{-1} in our numerical example) and some will tunnel through from the n to the p side. The forward tunnel current is proportional to the tunneling probability which has been seen to depend exponentially on the barrier thickness. The latter is proportional (see *Fig. 2*) to $(n_{ON} + p_{OP})/(n_{ON}p_{OP})$ and one thus realizes that the tunnel current will increase rapidly with increasing impurity content on either side of the junction. The basic model for the tunnel effect in *Fig. 3* is too simple to yield a quantitative description of the observed phenomenon. Some of the complications are listed in the following:

a. The exact shape of the potential barrier is not known but has a rather pronounced effect on the tunneling probability.

b. In a crystal we do not have a continuous range of permissible energy levels on the two sides of the barrier as assumed in the simple model of *Fig. 3*. Rather, we are concerned with two different ranges of discrete levels, the bands, and transitions between these are subject to additional energy and momentum conservation rules. Further difficulties arise from the complicated structure of the band edges involved in the transitions.

c. Serious and not fully known modifications occur in the band scheme for highly degenerate material and high electric fields. Similarly, the position of the impurity levels near the junction region is uncertain but they contribute to the transition probability.

d. In a number of semiconductors including germanium and silicon (but not, for example, GaAs, GaSb) tunneling involves interactions with phonons.[7]

Under an applied forward bias the barrier becomes thinner which should lead to an increased tunnel current. Actually, however, the opposite is the case: Under forward bias the overlapping range of permissible energy levels on the two sides of the junction (between E_{CN} and E_{VP} in *Fig. 4*) drops to zero and the bands begin to separate. The consequences of this shift in the relative position of the bands have not yet been analyzed satisfactorily, but it is known to cause a rapid decrease in the number of transitions and thus in the forward tunnel current, which vanishes at approximately 0.3 volts forward bias in germanium. The "forward-tunnel" current contribution to the *d-c* characteristics of the Esaki diode has been plotted as a dash-dot line in *Fig. 1*, making the explanation of the *I/V* curve complete. Actually there is usually an additional contribution to the current at the valley point which is of uncertain origin and has been termed "excess current." It has been reduced by improved manufacturing techniques.

One observes that the magnitude of the forward tunnel current under equilibrium conditions determines the peak current value and largely also the magnitude of the negative conductance, which, therefore, increase with increased impurity content.

4. Design, Construction and Characteristics[8]

The *magnitude* of the *negative* conductance, $-1/R = -G$, of the diode is proportional to the junction area and increases rapidly with increased impurity content on either side of the junction, as has been explained earlier.

For a plane-parallel abrupt junction the *capacitance* is given by

$$C = \frac{\epsilon A}{|x_N| + |x_P|} = A\left[\frac{\epsilon q}{2}\,\frac{1}{|v_{EQ} + v_{AP}|}\,\frac{n_{ON}p_{OP}}{(n_{ON} + p_{OP})}\right]^{\frac{1}{2}} \quad (6)$$

It increases proportionally with the junction area and approximately with the square root of the impurity density. Thus small capacitance and high negative conductance are seen to be two conflicting design requirements between which a compromise must be reached.

Eq. 6 indicates a non-linear increase of C with forward bias which is also observed in ordinary *p-n* junction diodes. In the negative-resistance region, however, the capacitance, although non-linear, does not seem to follow the predicted voltage dependence.[9] Because of the high shunt conductance exact measurements in this range are very difficult.

In a junction with 4×10^{19} cm^{-3} impurities on each side, the capacitance will lie between 1.5 and 3 $\mu f \cdot cm^{-2}$ depending on the applied bias. The tunnel diode has the highest capacitance per unit area among all junction devices.

The internal series resistance of the diode, r, codetermines the frequency response and must be made as small as possible. This is achieved by a very thin and highly doped semiconductor and good ohmic contacts.

For high power output the junction area should be made as large as the capacitance requirements permit.

Since the capacitance of the tunnel diode is so large, the series inductance in the circuit must be kept extremely small if high-frequency operation is to be achieved. Typically, for 1 *Kmc* operation, the series inductance must be less than 0.1 $m\mu h$. Sommers[10] describes a microstrip mount for the diode which fulfills this requirement. In other instances the diode has been mounted directly across the ends of a strip line or a coaxial cable.

The common technique for constructing the diode consists of alloying a metal pellet onto a wafer of highly doped semiconductor material. Sommers[10] mentions a 3 mil dot of In + 0.5% Ga + 0.5% Zn alloyed into 10^{-3} ohm-cm germanium doped with 2×10^{19} cm^{-3} arsenic impurities.[11]

The simplicity of the structure indicates that the eventual price of the unit will be quite low. *Fig. 5* shows a microphotographic sectional view of a tunnel diode.

The positions of the peak and valley points on the *I/V* characteristics of germanium diodes lie at approximately 70 and 300 *mv* respectively. Depending on the junction area and doping, peak current values lie between fractions of a milliampere and amperes. The best peak-to-valley current ratios run about 15 to 1.

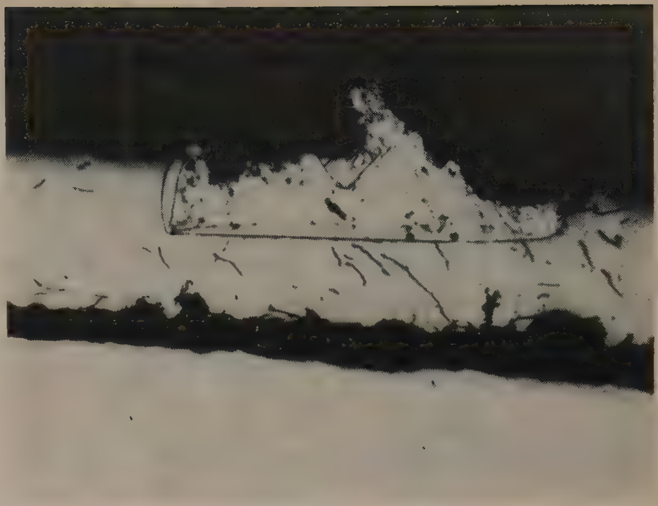


Fig. 5—Microphotographic cross section of silicon tunnel diode shows original n^+-type silicon wafer mounted on a metal plate and on the top surface a regrown p^+-type region along with the alloy from which the p^+ material was grown. Magnification 250x. (Courtesy of N. Holonyak, Jr., and I. A. Lesk, G.E., Syracuse, N. Y.)

In addition to germanium, tunnel diodes have been built of Si, GaAs, GaSb and InSb (the last operated at 78°K and below). Among these, gallium arsenide diodes (scheduled to be marketed by GE in the summer of 1960) appear the most promising with peak-to-valley current ratios of 60 to 1 and voltage swings to 1.2 v.

Negative resistances as low as -1 ohm with a junction area as small as 10^{-5} cm^2 ($C \simeq 50$ $\mu\mu f$) have been achieved by extremely high doping. Output powers range from watts at very low frequencies to microwatts in the kilomegacycle region. Diodes have been built which oscillate at a fundamental frequency of a few *Kmc* and which switch in 2 $m\mu$sec. Noise characteristics are mentioned later under "Applications."

The range of permissible operating temperatures for the tunnel diode is most likely greater than that for any other junction device made of the same material because the transition to intrinsic conduction occurs at very high temperatures due to the high impurity content. In addition, the resistance to nuclear radiation is also expected to be very high because the dominant mechanisms are to a first order independent of bulk and surface recombination. *Fig. 6* illustrates the nuclear and temperature resistance of a germanium tunnel diode. It must be pointed out, however, that even small changes in the characteristics due to temperature or other environmental conditions have a pronounced effect on small-signal performance as will become apparent below. The wide range of permissible operating temperatures unfortunately does not result in temperature stability of circuit performance (a characteristic possessed by many other semiconductor devices). The wider-bandgap materials seem to be superior in this latter respect, as one would expect.

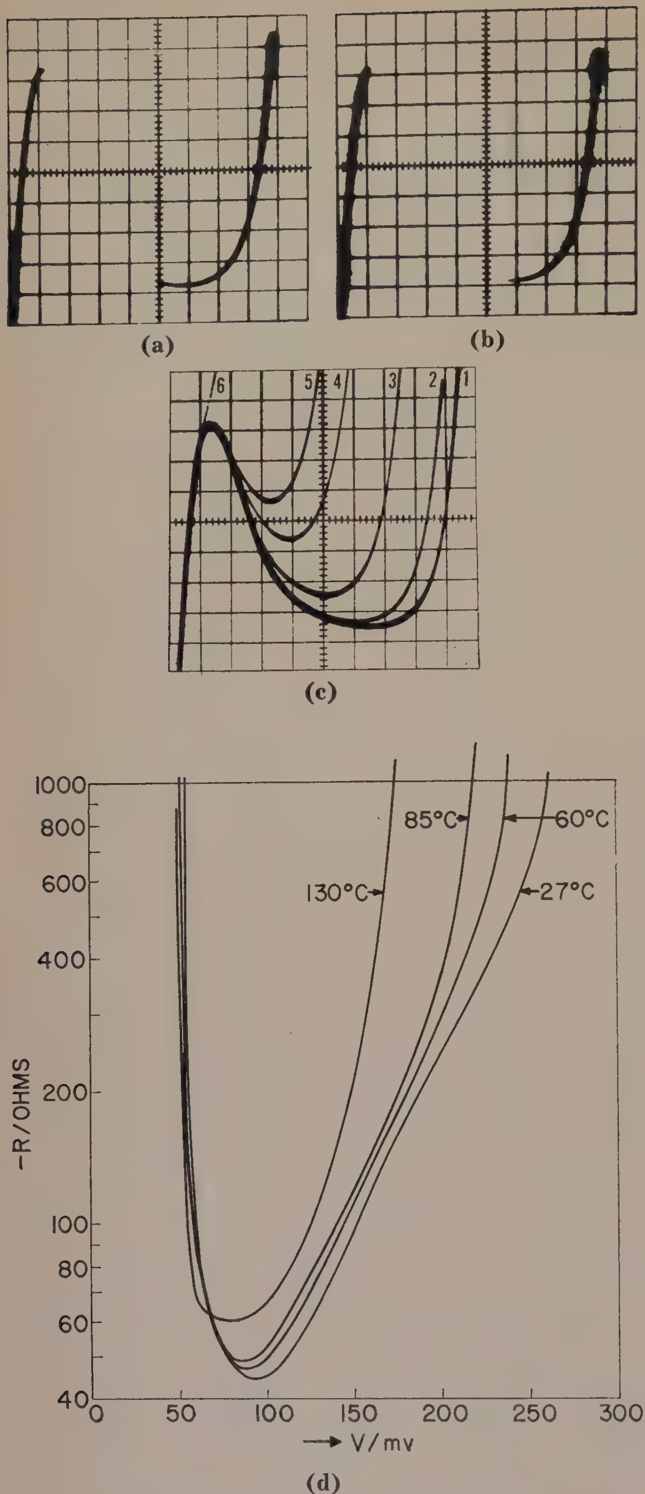


Fig. 6—Germanium tunnel-diode characteristics under nuclear bombardment and as a function of ambient temperature. (a) Forward characteristic before, and (b) after 10^{13} n.v.t. in the Godiva reactor (Measurements taken by F. Gordon, USASRDL, Fort Monmouth, N. J.) (c) Forward characteristic at (1) 26°C, (2) 50°C, (3) 100°C, (4) 160°C, (5) 200°C. Peak current is approximately 3 *ma*. (Measurements taken by M. Schuller, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J.) (d) Differential negative resistance of germanium tunnel diode at various temperatures measured versus operating point by a bridge method (signal amplitude approximately 6 *mv*). The measurements were taken by M. Schuller at USASRDL.

Equivalent Circuit

The customary equivalent circuit for the tunnel diode is shown in *Fig. 7a*. Since the negative resistance arises from an extremely fast process, the low-frequency I/V characteristic holds up to microwave frequencies and the only frequency dependence in the diode is introduced through its junction capacitance, C.

Depending on the package used, one may have to include its series (lead) inductance, L_p, into the equivalent circuit.

Fig. 7b shows some of the symbols which have been proposed for the tunnel diode.

5. Applications

D-C Bias Circuit

To obtain a stable *d-c* operating point in the negative-resistance region, one may use a supply circuit such as the one shown in *Fig. 8b* with the supply voltage, V_B, and the internal resistance of the source, R_o, chosen such that the *d-c* load line intersects the diode characteristics at only one point, (I_o, V_o). The necessary conditions are shown in the figure. After the values for $-R$ and V_1 of the diode have been determined from a plot of the characteristics, and a desired operating point (I_o, V_o) has been chosen, the equation given in the figure is used to find R_o and V_B. R_o is the internal resistance of the source as it presents itself at the two terminals. In certain cases it must be very low due to the condition $R_o < R$, and it may then be realized by a circuit as shown in *Fig. 9*. It has the added advantage that the necessary supply voltage, V_B, which usually lies at a few tenths of a volt, may be stepped down from any convenient source. Series inductances in the supply circuit must be avoided to prevent unwanted oscillations. The circuit of *Fig. 9* has the property that any inductance, L', in the voltage supply, appears at the terminals of the source reduced by a factor of approximately $(R'/R'')^2$. It may, therefore, be used to display the diode characteristics on an oscilloscope using a transformer (with inductance L) as the sweep supply (see *Fig. 10*). *Fig. 11c* shows how one may completely separate the *d-c* supply circuit from the *a-c* path by shorting it with a very large capacitance C'.

A-C Circuits

Fig. 11 shows the two basic configurations for negative-resistance oscillator circuits. We shall first consider the circuit in *Fig. 11a*. We find that:

Diode

$$i = vY/(1 + rY) \tag{7}$$

where

$$Y = -1/R + j\omega C \tag{8}$$

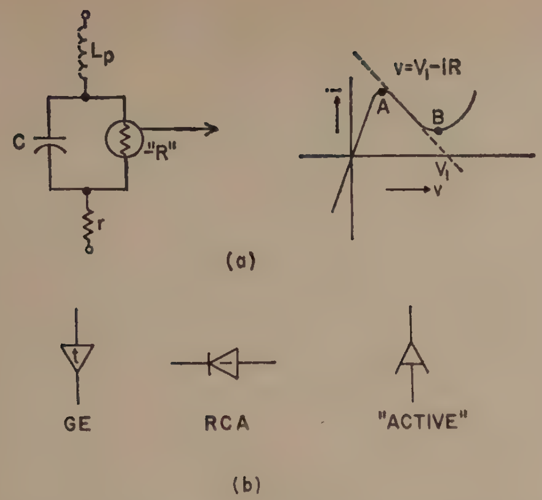


Fig. 7—(a) Equivalent circuit and low-frequency characteristic of the tunnel diode. In the negative-resistance region beween peak and valley points, "A" and "B," the curve may be approximated by a straight line with slope —*R*. *C* is the junction capacitance, *r* is the equivalent series loss resistance. (b) Symbols proposed for the Esaki diode: General Electric, "t" for "tunnel"; RCA, "—" for "Negative resistance"; 3rd possibility, "A" for "Active" diode.

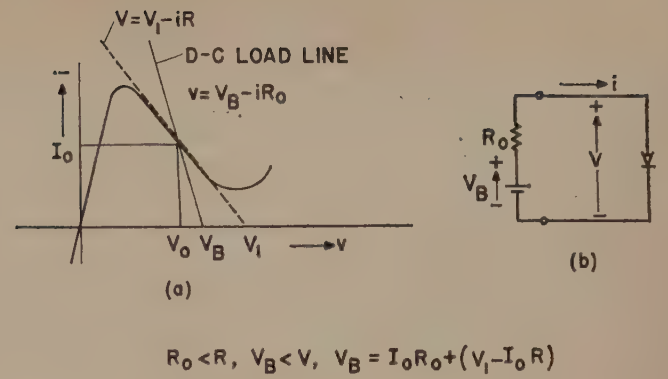


Fig. 8—Bias arrangement to obtain stable *d-c* operating point in the negative resistance region.

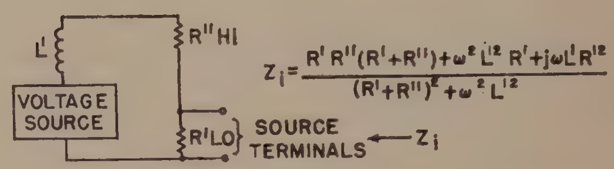


Fig. 9—D-C supply with low internal resistance and low internal inductance.

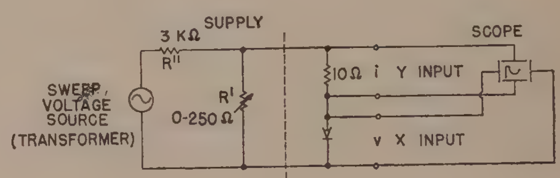


Fig. 10—Circuit arrangement for oscilloscope display of diode characteristics. (Courtesy M. Schuller, USASRDL, Fort Monmouth, N. J.)

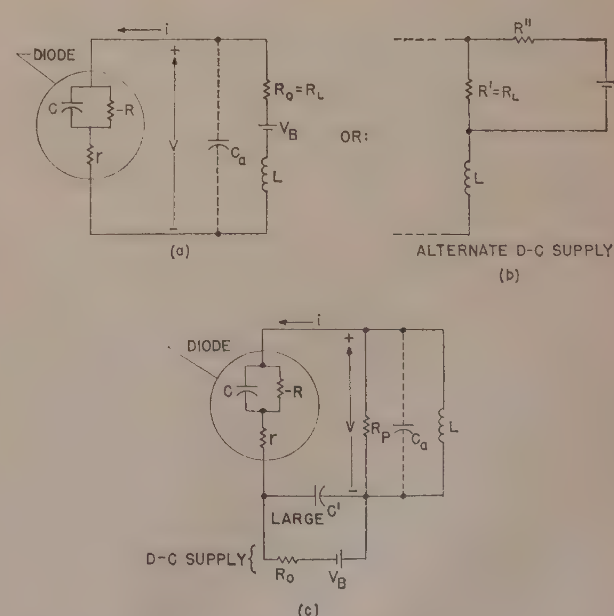


Fig. 11—Basic negative-resistance oscillator circuits.

External Circuitry

$$i = -v/Z \tag{9}$$

where

$$Z = R_L + j\omega L \tag{10}$$

Setting the two expressions for the current, i, equal to each other, we find that oscillations may occur ($v \neq 0$) only if

$$-1/Z = Y/(1 + rY) \tag{11}$$

The imaginary part of this equation yields for the frequency of oscillation

$$\omega^2 = 1/(LC) - 1/(RC)^2 \tag{12}$$

and the real part yields for the starting condition

$$R_L = -r + R/(1 + \omega^2 R^2 C^2) \tag{13}$$

One notices that $R_L < R$, otherwise no oscillations would occur. At the same time, the condition for a stable *d-c* operating point in the negative-resistance region would be violated. From Eq. 13 it is apparent that the highest frequency of oscillation is achieved for $R_L = 0$, namely

$$\omega_{max} = \frac{1}{C}\left[\frac{1 - r/R}{Rr}\right]^{\frac{1}{2}} \simeq \frac{1}{C\sqrt{Rr}} \tag{14}$$

One observes that for high frequency of operation, C, R and r of the diode should be as small as possible. To achieve oscillations at lower frequencies, it is more advantageous to add an auxiliary capacitance, C_a, (see *Fig. 11*) rather than increase the inductance, L, because due to the reduced L/C ratio of the resonant circuit, the output wave form is more sinusoidal. The

frequency of oscillation may then be calculated by replacing C by $C + C_a$ in the formulae (and neglecting the effect of r).

In the circuit of *Fig. 11c*, we have for the external circuitry

$$i = -[1/R_P + 1/(j\omega L)]\, v \qquad (15)$$

and one finds in an analogous way

$$\omega^2 = \frac{1}{CL}\,\frac{(1 - r/R)}{(1 + r/R_P)} = \frac{(1 - r/R)^2}{LC - r^2C^2}$$

$$= \frac{(1 - r/R)\,[1 + (r - R)/R_P]}{C^2rR(1 + r/R_P)} \qquad (16)$$

and

$$R_P = [(1 - r/R)^2 + r^2\,\omega^2C^2]/[(1 - r/R)/R - r\omega^2C^2] \qquad (17)$$

$$L = \frac{1}{\omega^2C}\,\frac{(1 - r/R)}{(1 + r/R_P)} = (1 - r/R)^2/(\omega^2C) + r^2C \qquad (18)$$

One observes that stable oscillations are achieved only for

$$R_P > R \qquad (19)$$

This condition is not in conflict with any requirement on the *d-c* supply circuit which is entirely separated from the *a-c* path. If it is not satisfied oscillations will occur and the circuit may be operated as an amplifier as explained below. As $R_p \rightarrow \infty$ one reaches, of course, the same maximum frequency of operation as given by Eq. 14. Sinusoidal oscillations at lower frequencies are again best achieved by adding an auxiliary capacitance, C_a.

So far we have derived conditions for oscillation and expressions for the frequency of tunnel diode oscillators. To complete the circuit-design theory, we would have to add a discussion of amplitude limitation, power output and distortion. These, however, are more advanced subjects which require the numerical or graphical solution of differential equations[12] and exceed the scope of this article. As the amplitude increases and the instantaneous operating point swings deeper into the positive-resistance regions adjacent to the negative-resistance range, one finds the transition to the relaxation oscillator which can here be analyzed in exact form employing advanced circuit techniques.[12]

As the frequency of oscillation depends on the capacitance, C, of the tunnel diode as well as on its differential negative resistance, $-R$, a tunnel-diode oscillator may be tuned by changing its operating point. The non-linearity of the capacitance may also be used for frequency conversion and mixing while the negative resistance of the diode is simultaneously used for oscillation and amplification.[13]

Since the voltage swing of the device is limited to approximately 0.45v in germanium, 0.75v in silicon and 1.2v in gallium arsenide, higher output voltages must be achieved by transformation which, however, is difficult because inductance values must be kept very low. At high frequencies the permissible junction area and thus the current are limited by capacitance requirements so that output power drops with increasing frequency. Because of the small *d-c* power requirements on the other hand, tunnel diode oscillators operate with high efficiency.

(To be continued)

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The Hall Effect
Applications in Electrical Measurements

L. E. FAY III*

The Hall effect, used for many years as a tool in experimental physics has recently been noticed by electrical engineers who were in need of a device having some of the characteristics of the Hall effect. Modern research in materials and geometrical configuration has developed devices of good enough efficiency to begin to be useful in engineering applications. This article is a review of most of the simple applications of the Hall effect covering the elementary electrical circuit theory upon which these applications are based.

THE HALL EFFECT, known to physicists since 1879 has, in recent years, been given considerable attention by electronic engineers because of certain very interesting properties.

The Hall effect[1] is a galvanomagnetic effect which is the solid state analogue to the magnetic deflection of the electron beam in a television tube. An electric current, I, is passed through a crystal in a direction perpendicular to a magnetic field, B. The crystal is usually a thin rectangular plate oriented as in *Fig. 1*. The current carriers, either electrons or holes, are deflected according to the usual left hand rule in a direction mutually perpendicular to both I and B. Some of the deflected carriers pile up at the edges of the crystal and generate an electric field which opposes the magnetic deflection. When the electric field equals the magnetic force, an equilibrium voltage is established across the edges of the crystal, which voltage is described as

$$V_H = \frac{10^{-8} R_H I_S B}{t}$$

where t is the thickness of the crystal in cm, I_S in amperes and B in gauss are as previously described, and R_H, the Hall coefficient measured in cm^3/coulomb is a proportionality factor which depends upon bulk properties of the crystal such as resistivity and carrier mobility. Typical values of R_H are shown in Table I. There are correction factors for crystal geometry and size of voltage lead contacts. It has been noticed by the author that for large soldered voltage contacts, the output voltage for crystals cut from the same or comparable bulk material (n-type germanium, about three ohm-cm), varied directly as the resistance between the leads, while the short circuit current remained essentially constant. For any particular crystal, an empirical correction factor may be obtained or the corrections just absorbed into R_H. A crystal with a large R_H is desired so a semiconductor is usually used. Commonly used materials are silicon, germanium, indium antimonide, and indium arsenide.[2,3,4]

From the foregoing considerations, it is seen that the Hall voltage is proportional to the product of a driving current and a magnetic field. In an electromagnet, the effective field at the crystal can be varied in three independent ways: (1) by changing the magnet current; (2) by changing the orientation of the crystal in the field; (3) by changing the distance from the crystal to the magnet. Thus the experimenter has at his control a voltage which is proportional to the product of up to four independent variables. With so many degrees of freedom, a large number of interesting applications can be made.

*This article was written while the author was with the Bendix Aviation Corp. He is now associated with the Computer Products Division of the Excello Corp., Walled Lake, Mich.

Table I

Material	R_H (typical) $\frac{cm^3}{q}$
Germanium	2 x 10^3
Silicon	15 x 10^3
Indium Antimonide	0.6 x 10^3
Indium Arsenide	0.8 x 10^3

Simple Applications

Perhaps the simplest and most straightforward appli-

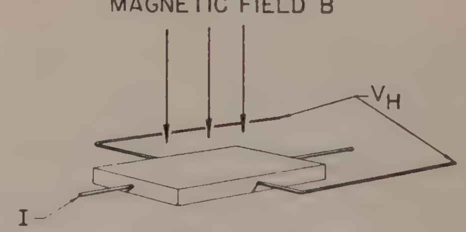

Fig. 1—The Hall effect.

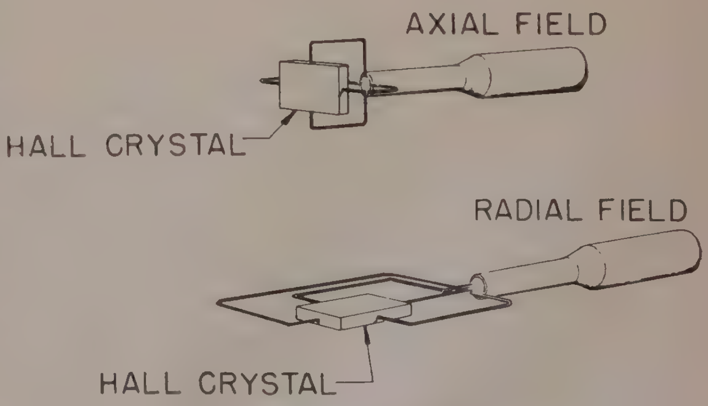

Fig. 2—Gaussmeter probes.

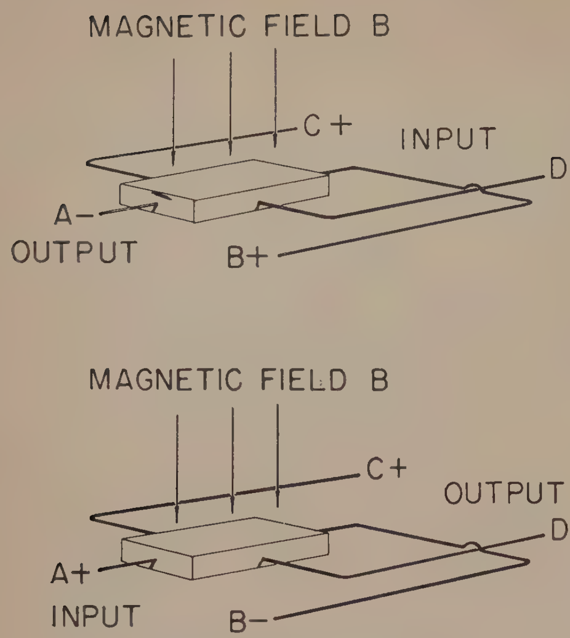

Fig. 3—Hall effect gyrator.

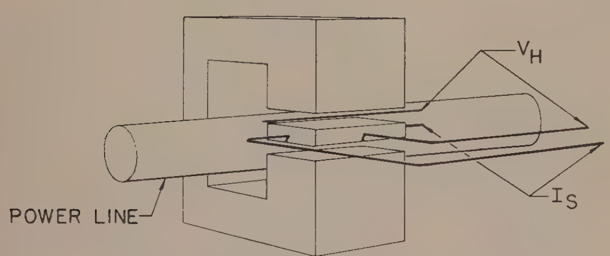

Fig. 4—Hall effect ammeter.

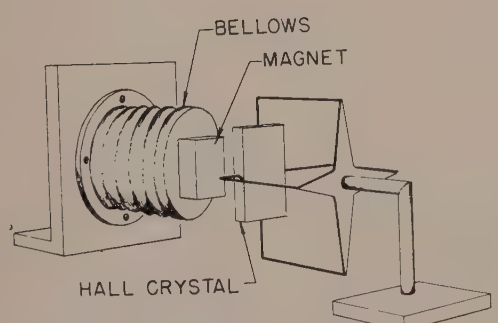

Fig. 5—Hall effect distance indicator.

cation is a gaussmeter. The crystal is mounted on a probe so that it may be placed perpendicular to the field to be measured (*Fig. 2*) It is calibrated at some known field for one or more currents depending upon the range of the output meter. Although theoretically a one-point calibration is sufficient, calibration at several fields will reduce errors due to nonlinearity introduced by high fields or loading of the crystal. When measuring a field, the crystal should be rotated slightly to get maximum output for that location. This assures that the crystal is perpendicular to the field.

The Hall effect may be used as a gyrator[5] (*Fig. 3*), an interesting example of a nonreciprocal circuit. A nonreciprocal device is defined as one which will pass information in two directions through the device, (output and input terminals may be interchanged) but operates upon the information in a different manner in each of the two directions. The best known gyrators are the ferrites used to rotate the plane of polarization of a wave in a waveguide. The Hall effect gyrator reverses the polarity of a signal when the input and output are interchanged. If a direct current is driven between A and B so that A is positive, conditions of magnetic field and carrier-type can be adjusted so that of the output voltage measured between C and D, C is the positive terminal. If C and D are now made the current or input leads, with terminal C positive, terminal A will be the negative terminal of the output voltage between A and B.

Another simple application is in an ammeter, either *a-c* or *d-c*, which is not a series element in the circuit (*Fig. 4*). The current in the wire induces in the yoke a magnetic field proportional to the current. The Hall voltage at constant crystal current is proportional to the magnetic field and thus to the field current. This device will work best at very high currents where conventional ammeters are difficult to calibrate and use.

The fact that the field of a magnetic pole follows the inverse square law [6] (*Fig. 5*) can be applied to a Hall effect distance meter. Either the crystal or the magnet can be mounted on a movable rod or bellows with the other element fixed. Motion of the rod or bellows would be detectable in the variations of V_H.

If the crystal is mounted on a rotating shaft in a uniform magnetic field in such a way that electrical contacts are made through slip rings or long wires to allow for several revolutions of the crystal, the number of applications increases greatly. The same result is obtained if the crystal is fixed and the magnet rotated. The effective magnetic field intercepted by the crystal varies sinusoidally with θ, the angle of rotation of the crystal so that $B_{eff} = B_{max} \sin \theta$ or $B_{eff} = B_{max} \cos \theta$ depending upon the choice of zero point. (*Fig. 6*).

The obvious application of this is a low frequency sine wave generator. If some hi-fi fan is boasting too much about the bass response of his system, just fasten a Hall crystal to the second hand shaft of a clock and let him try one cycle per minute. That should stop him. Commercially, the Hall effect may prove useful in applications where a smooth (non-step function) sine wave at extremely low frequency is needed because, unlike conventional generators, the output voltage is independent of rate of rotation. This device can be used as a tachometer by mounting either the magnet or crystal on the shaft and reading the output frequency on an oscilloscope or other frequency meter. In the same manner, the home experimenter can make a simple anemometer.

Analogue Computers

Continuing into the field of analogue computation, one finds the relation $V_H = k\ I\ B_{max} \sin \theta$ (or $\cos \theta$) to be potentially useful in several different applications. For

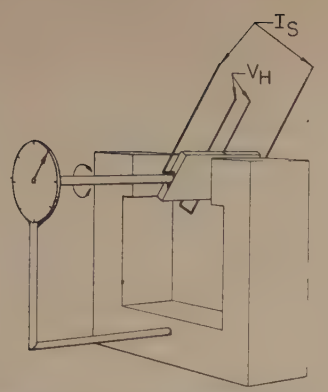

Fig. 6—Rotating Hall crystal.

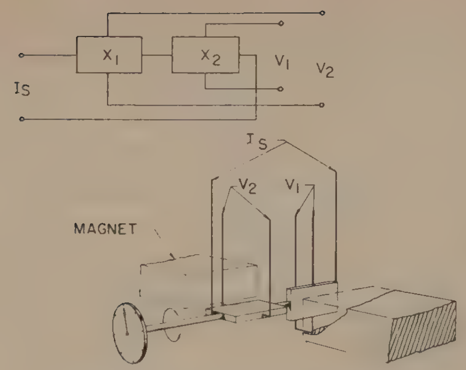

Fig. 7—Sine-cosine generator.

example, in the solution of Fourier series one has many terms of the form a ($\cos\theta \sin\phi + \sin\theta \cos\phi$) or any other sin-cos combination. The rotation is calibrated in two scales 90° apart and proportional to θ so that using one scale the output reads $a \sin\theta$ and using the other, $a \cos\theta$. To solve, $a \cos\theta \sin\phi$, the crystal current is set to be proportional to a and the cosine rotation scale set to θ. The output reads $V_H = ka \cos\theta = b$. The crystal current is then set to be proportional to b and the sine rotation scale set to ϕ. The output now reads $V_H = k^2a \cos\theta \sin\phi$. The procedure is repeated for $a \sin\theta \cos\phi$. A refinement of this unit is to put two crystals in series with the crystal current and rotating about the same current axis but with the voltage axes rotated by 90° so that with only one dial scale one crystal output reads $\cos\theta$ and the other reads $\sin\theta$ (*Fig. 7*). One can then read $a \cos\theta$ and $a \sin\theta$ simultaneously on two output meters.

This configuration can be used in an analogue computer unit known as a resolver, a device which transforms the variables r and θ of the polar coordinate system into the variables $x = r\cos\theta$ and $y = r\sin\theta$ of the rectangular coordinate system. An interesting demonstration of this unit is to set a current magnitude (peak of rectified *a-c*) and an angle on the resolver and to read the magnitude and angle on an oscilloscope by feeding the two output voltages to the x and y plates (*Fig. 8*). This device can also be used as a direction indicator. The two phased crystals are needed as each crystal shows mirror symmetry in its output if allowed to rotate more than 180°.

A further refinement of the rotating crystal multiplier is to cascade the crystals so that several multiplications are performed in one operation (*Fig. 9*). *D-C* amplifiers must be used to drive a succeeding crystal from the output of the previous one. With a large selection of crystals available, it is possible to choose a crystal of high output and proper impedance to directly drive the next crystal, which is chosen for low input requirements. If each crystal pair in a cascade is mounted with its own individual shaft and magnet, n dimensional multiplications of the form $a \sin\alpha \cos\beta \cos\gamma \ldots \sin n$ can be performed. Two or three stage units should be quite useful in some of the tedious calculations of this type made in x-ray crystallography.

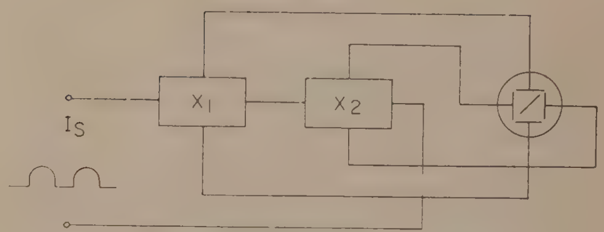

Fig. 8—Oscilloscope display of resolver.

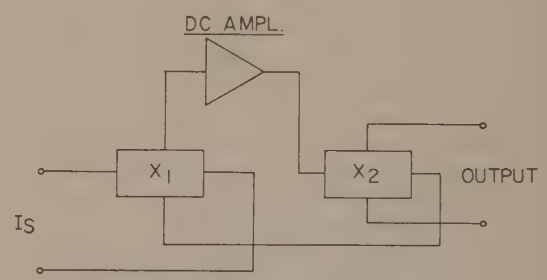

Fig. 9—Cascaded Hall crystals.

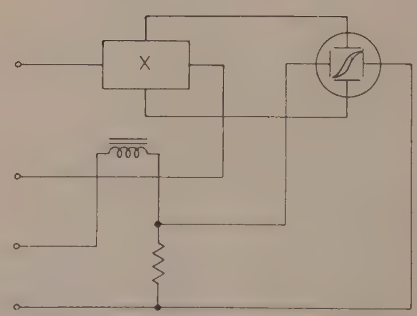

Fig. 10—Oscilloscope display of magnetic hysterysis curve.

Applications With Electromagnet

If an electromagnet is substituted for the permanent magnet, the field B_{max}, becomes a function of the magnetizing current, linear over some range for most magnetic materials. The hysterysis curve of the material of the core of the electromagnet may be displayed on an oscilloscope by putting the magnetizing current (proportional to H) on the x-axis and the Hall voltage (proportional to B) on the y-axis. (*Fig. 10*) This circuit can be

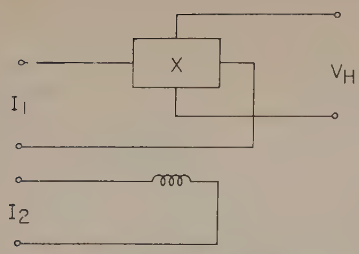

Fig. 11—Hall effect multiplier.

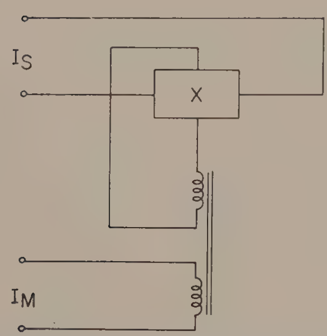

Fig. 12—The "ruckgekoppelte" Hall-generator.

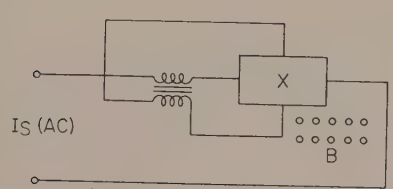

Fig. 13—Feedback to the current lead.

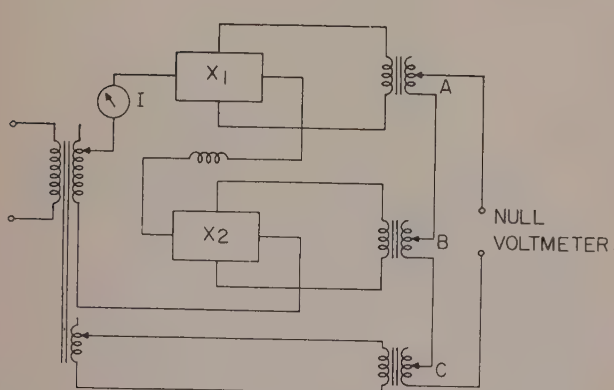

Fig. 14—Quadratic computer.

used in digital computation to register coincidence or overlap of events as there is no Hall voltage unless there is both a crystal current and a magnetizing current. By varying both crystal current and magnetizing current over a linear range, a simple analogue multiplier is made.[2] (*Fig. 11*). This can be used alone, so $V_H = k\, I_1\, I_2$ or it may be used to introduce another linear variable into the trigonometric multipliers previously described so that $V_H = k\, I_1\, I_2 \sin \theta$.

Feedback Effects

If the magnetic field obtained by loading the output with a coil is about the same as the driving field, very interesting effects can be obtained by feeding the output back into the input. In the back coupled Hall generator[4] (*Fig. 12*), a negative resistance device was made by driving the voltage output and a coil in series as the load of a vacuum tube. The amount of negative resistance is controlled by the driving current in the crystal. A variable pulse length generator circuit was made with pulse length controlled by the crystal driving currents. If *a-c* crystal current were used, feedback into the driving current circuit could be used in much the same manner as in the magnetic circuit (*Fig. 13*). Such feedback devices, especially in the negative resistance regions, may have wide circuit applications. Frequency response of these circuits, like all Hall effect circuits, is limited by the frequency limitations of associated circuit components as the Hall effect is frequency independent from *d-c* to far infrared.

More Computer Applications

If the Hall crystal is driven by a constant *a-c* field and a variable *d-c* crystal current (or vice-versa) it becomes a modulator, giving an *a-c* output proportional to a *d-c* input. Modulators are widely used in analogue computers.

An interesting application of the *a-c* Hall effect is in a computer which finds the real roots or the real part of complex roots of the quadratic equation $ax^2 + bx + c = 0$ (*Fig. 14*). This circuit is very similar to the quadratic analogue computer often shown to sophomore electrical engineers which uses a linear taper and a square taper potentiometer. The constants a, b, and c are set on their respective variable transformers. The crystal current is then varied to the value at which it reads zero for a real root, or reads a minimum for the real part of a complex root. Changing b from plus to minus (180° phase shift) has the same effect as reversing the sign of x, so the crystal current may vary from $+x$ to $-x$ in the range of the device. The device works as follows. V_a is proportional to I, a, and B_a. However, B_a is also proportional to I so $V_a = k\ a\ I^2$. V_b is proportional to I, b, and B_b. If this proportionality constant times B_b (also a constant) is made equal to k, $V_b = k\ b\ I$. V_c is set equal to $k\ c$. Thus, $V_a + V_b + V_c = k\ (a\ I^2 + b\ I + c)$. The value of I at which $V_a + V_b = V_c = 0$ is a real root of the equation. If no null is read, but only a minimum value of the voltage sum, it is easily shown that this is the real part of a complex root. Set $ax^2 + bx + c = m$, a variable constant. Now let $\frac{\delta m}{\delta x} = 0 = 2\,ax + b$. $x = \frac{-b}{2a}$, the real part of $x = \frac{-b \pm \sqrt{b^2 - 4\,ac}}{2\,a}$ when x is complex. $\frac{\delta^2 m}{\delta x^2}$ is positive, indicating that x is a minimum.

Electrical Instrumentation

If the crystal and magnetic field are driven by different frequency currents, the Hall effect acts as a heterodyne generator or mixer (*Fig. 15*). $V_H = k\ I_1 \sin \theta\ I_2 \sin$

$\phi = \frac{k\, I_1\, I_2}{2}$ [cos $(\theta - \phi)$ − cos $(\theta + \phi)$]. This device is useful well up into the microwave region.

A wattmeter can be made using the magnetic field arrangement as in the Hall effect ammeter and drawing the crystal current from between the lines concerned (*Fig. 16*). As the crystal is a pure resistance, the crystal current will be in phase with the line voltage, $I_1 = k\, V_o \sin \omega t$, while the magnetic field, derived directly from the line current, is in phase with the current, $B = k' I_o \sin (\omega t + \phi)$. So $V_H = k''\ V_o\ I_o \sin \omega t \sin (\omega t + \phi) = k''\ V_o\ I_o \sin \omega t\ (\sin \omega t \cos \phi + \cos \omega t \sin \phi) = k''\ V_o\ I_o \left(\sin^2 \omega t \cos \phi + \frac{\sin 2\, \omega t}{2} \sin \phi\right)$. The *d-c* component of this is $\frac{1}{2\pi} \int_0^{2\pi} V_H\, d\omega t = k''\ V_o\ I_o \frac{1}{2\,\pi} \int_0^{2\pi} \left(\sin^2 \omega t \cos \phi + \frac{\sin 2\, \omega t}{2} \sin \phi\right) d\omega t = \frac{k''\ V_o\, I_o}{2} \cos \phi = \frac{k''}{2} P$ in watts. In the microwave wattmeter (*Fig. 17*), the Hall effect measures $E \times H = P$ directly. In the same manner a phase shift meter can be made for use with any two signals of the same frequency provided that correction is made for the inductance of the magnet winding.

It has been pointed out that when the Hall crystal and magnetic field are driven by two different frequencies, a heterodyne output is obtained, while if both are driven by the same frequency a signal of twice the driving frequency with a *d-c* component equal to the peak value of the signal is generated provided both driving currents are in phase. If they are out of phase by angle ϕ, the *a-c* component of the output is distorted and the *d-c* component reduced by a factor of $1/2 \cos \phi$. This information has been applied by the Russians [7] to make a wave analyzer. Two magnets are driven by two signals of the same, but variable frequency and shifted in phase so that $I_1 = I_o \sin \omega t$ and $I_2 = I_o \cos \omega t$. The crystals are driven in series by the wave to be analyzed, which may contain many frequencies at various phase relations. One *d-c* output will read $V_1 = k\, I_o\, I_x \cos \phi$ and the other $V_2 = k\, I_o\, I_x \sin \phi$, so ϕ, the phase angle of I_x with respect to I_o can be found as $\phi = \tan^{-1} \frac{V_2}{V_1}$ and I_x, the ωt component of the analyzed wave, determined.

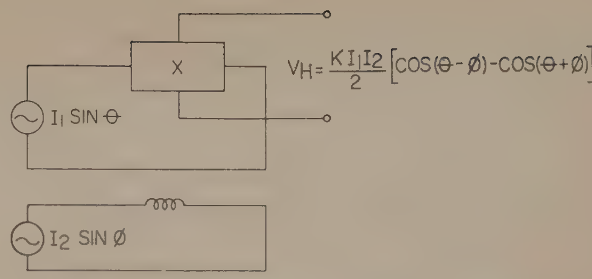

Fig. 15—Heterodyne generator or mixer.

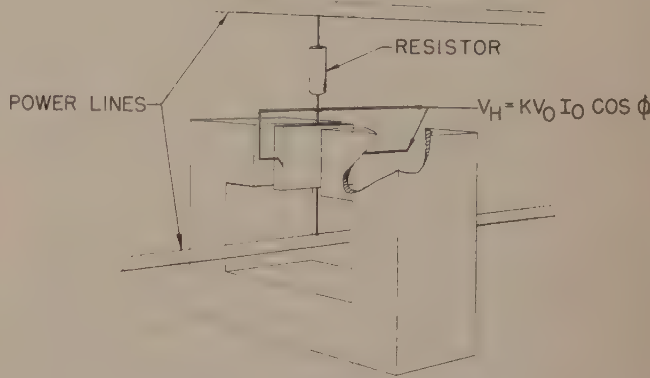

Fig. 16—Hall effect wattmeter.

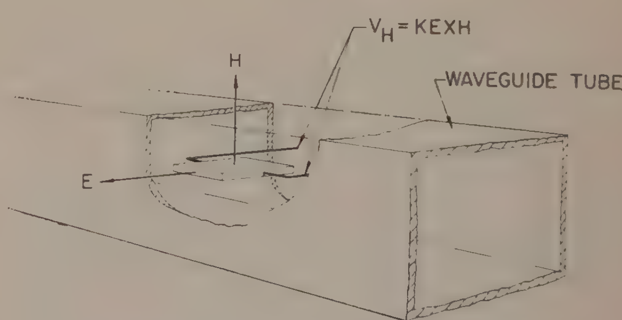

Fig. 17—Microwave wattmeter.

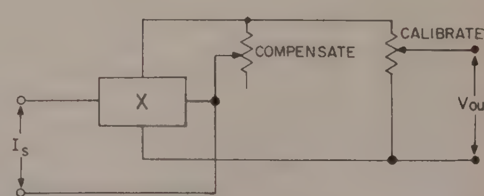

Fig. 18—Compensating and calibrating potentiometers.

General Circuit Considerations

Certain aspects of Hall effect circuitry may be a little disconcerting to a man trained in vacuum tubes. There is no common ground between input and output. The output voltage is balanced with respect to a bias point which varies directly with the crystal input current. This causes considerable trouble in the use of *d-c* amplifiers, power supplies, and electronic millivoltmeters. Indium arsenide and indium antimonide make very low impedance devices, usually about one ohm. Germanium and silicon crystals range from a few ohms to a few thousand ohms depending upon the shape of the crystal and purity of the material. Hall effect devices are current rather than voltage operated. At high magnetic fields the linearity of the output with field is a function of load impedance ranging from positive to negative curvature. For indium arsenide the linear load is about seven times the internal impedance of the crystal.[8] This factor may be different for other semiconductors. The maximum

usable current is determined by the heating of the crystal. As the temperature of the crystal increases, the resistivity and, as a result, the Hall coefficient varies, causing V_H to be non-linear with respect to I_S. Maximum current is that which causes maximum non-linearity tolerable in any particular application. In the case where the voltage electrodes are not properly placed, compensating potentiometers are used to make the zero field voltage equal zero (*Fig. 18, 19*). This condition is a necessity for many applications. A calibrating potentiometer is used to make the output fit some desired scale. These auxiliary circuits have little effect in the no load case but if not chosen carefully will destroy linearity of the device upon loading. In *a-c* applications care must be taken to avoid extraneous signal pickup by the leads.

Three Terminal Hall Effects

Only the conventional Hall effect configuration has been discussed. There is also a three terminal configuration[5] (*Fig. 20*). Three leads are attached to a semiconductor crystal so they are at the vertices of a triangle. The current enters the crystal through one lead and leaves through the other two. (This is the simplest case. More than one input lead and more than two output leads can be used.) In a symmetrical case the currents in the two output leads will be equal. Application of a magnetic field perpendicular to the plane of current flow will cause a deflection of current carriers in a direction mutually perpendicular to the direction of current flow and the direction of the magnetic field and of a magnitude proportional to the strength of the magnetic field. Because of this deflection, more carriers will appear at one output lead than at the other. Depending upon the relation of the impedances in the output circuit to the crystal impedance either case 1 where R_3 is large, and R_1 and R_2 are small compared to the crystal impedance, the current in one output lead will increase and the current in the other will decrease or case 2 where R_3 is small, and R_1 and R_2 are large compared to the crystal impedance, a voltage comparable to the Hall voltage will be developed between the output leads. This can be applied almost anywhere the conventional Hall effect can and perhaps other applications can be found.

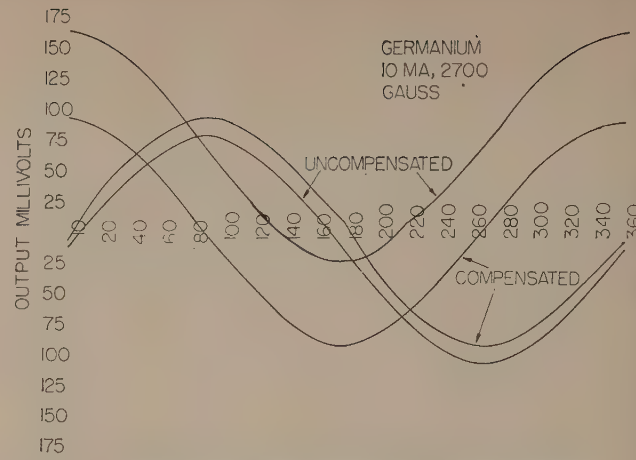

Fig. 19—Effect of compensating potentiometer.

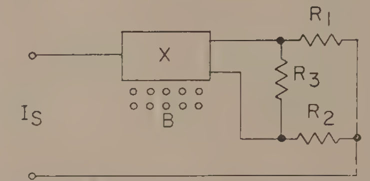

Fig. 20—Three terminal Hall effect.

Conclusion

The writer does not claim originality for most of these ideas. Many of them are quite old. If an application has been seen in two or more publications, no credit line was given. The writer wishes to thank Mr. M. T. Haddad of the Research Laboratories Division of the Bendix Aviation Corp. for assistance in literature survey.

It is hoped that a paper of this nature may stimulate some interest in Hall effect circuit experimenting.

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Application of Transistors To Video Equipment

Part 1

K. HIWATASHI* Y. FUJIMURA* K. SUZUKI* N. MII*

This is the first of a series of articles describing developments in the transistorization of television transmitting equipment in Japan. The portable camera-transmitter is described in this installment. Future articles will treat the sync-signal generator, and the image orthicon camera.

TRANSISTORIZED VIDEO EQUIPMENT, such as portable camera-transmitters, standard sync-generators and field-type image-orthicon cameras have been developed at the NHK Technical Research Laboratory. In fact, any television equipment can now be fully transistorized with the use of commercially available transistors, because of advances made in transistor and circuit techniques. High power horizontal deflection circuits and *uhf* circuits, however, still present difficulties under the present transistorization techniques.

Portable Camera-Transmitter

The portable camera-transmitter (PCT) shown in *Fig. 1* is designed for field pickup. It contains approximately 120 transistors, a 1-inch vidicon (6326), a 3-inch picture tube (M-7136), a pencil tube (5876) and two high-voltage rectifiers (both 5642). It was developed from the pilot type which was manufactured in 1955 for experimental purposes and has been effectively used for televising several special events since April 1958.

PCT Specifications

The features of this equipment are as follows:

Weight	18 kg.
Communicating distance	0.5 mi. (1.5 mi. with a directional antenna)
Operating time	3 hrs. or more
Radio frequencies used	2000 *mc* (video and sound) and 153 *mc* (external sync-signal and intercommunication)
Optical system	Two 16-mm turret type lenses
Overall signal to noise ratio	33 *db*.
Resolution	400 lines

The camera contains a preamplifier, a deflection circuit, a blanking amplifier and a view-finder, and is shown in block diagram form in *Fig. 2*.

Preamplifier

The preamplifier contains 13 drift transistors and has a current gain of 80 *db*. The schematic diagram of aperture correction in the amplifiers is shown in *Fig. 3*.

With the variable capacity of the emitter properly adjusted, the phase compensator (*T5*) minimizes the phase distortion of the high-peaked circuits consisting of *T6-T7* and *T8-T9*.

Fig. 1—Transistorized portable camera-transmitter.

*Television Research Section, NHK Technical Research Laboratory, Tokyo, Japan.

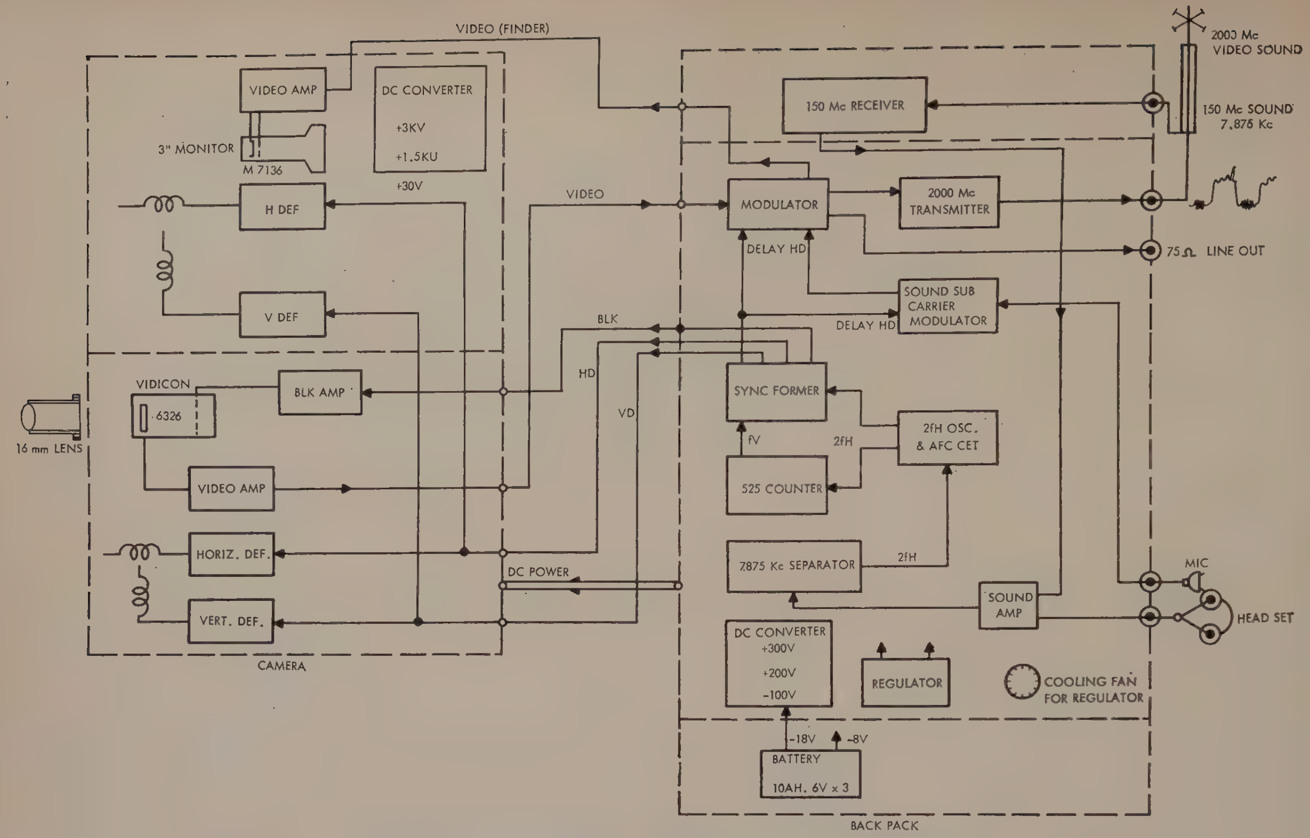

Fig. 2—Block-diagram of portable camera-transmitter.

With these circuits, the overall frequency characteristic shows a possibility of about 9-*db* aperture correction on 3-4 *mc*.

The output video signal of the preamplifier, approximately 5 *ma* peak to peak, is fed to the modulator through the camera cable, and is inserted into the intercommunication subcarrier after being clamped with delayed *HD*. The signal output of the modulator then modulates the grid of the 2000-*mc* transmitting tube (5876) with 0.5- to 1-volt signal.

Sound Modulator

The schematic diagram of the sound modulator is shown in *Fig. 4*. *T5* is a 2.7-*mc* crystal oscillator, and this carrier is amplitude modulated with the audio

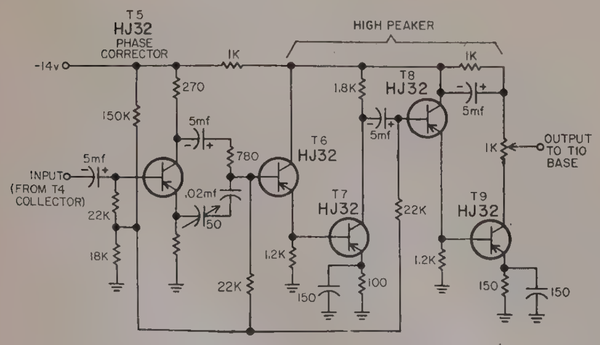

Fig. 3—Schematic diagram of aperture correction.

signal of the output of *T1*. The modulated 2.7-*mc* signal is gated by the delayed HD pulse, which is fed into the base terminal of *T3*.

The output of the 2.7-*mc* *L-C* filter, which has the waveform shown in *Fig. 4*, is inserted into the blanking period of the video signal. The cameraman can talk freely with the base station using two ways of the time-divided multiplex channels—the 2000-*mc* channel and the *fm* channel (153 *mc*).

The 2000-*mc* transmitter of this PCT is frequency modulated and uses a circular polarized waveform for protection from the multipath interference of microwaves. The frequency modulation is achieved by modulating the grid of the transmitter tube. In this case the *fm* deviation is about 2 *mc* against the video input of 0.5 volts.

The sync-lock is due to the synchronized external signal from the base station. Because of the adoption of this system, the random disturbance encountered in a microwave transmission does not interfere with the sync signal of the other camera chain at the base station and it permits the mixing of the video signal of the PCT in other camera outputs at the base station.

The external sync-signal, which is a 7.875 *kc* sine wave corresponding to ½ the horizontal frequency, comes from the *fm* transmitter of the base station with a multiplexed sound signal on 153 *mc*, *vhf*. This sync and sound signal drives the frequency separator circuit. The frequency separator circuit shown in

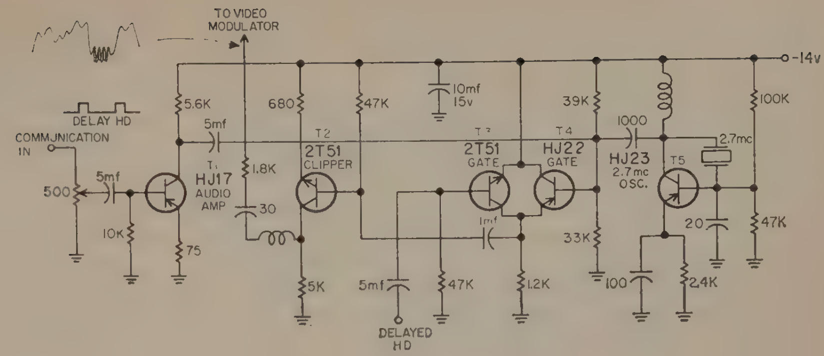

Fig. 4—Schematic diagram of sound modulator.

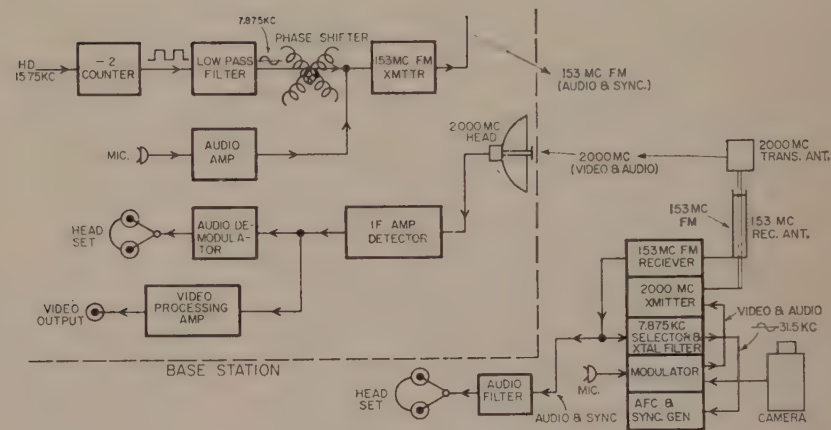

Fig. 5—Sync-lock and intercommunication system.

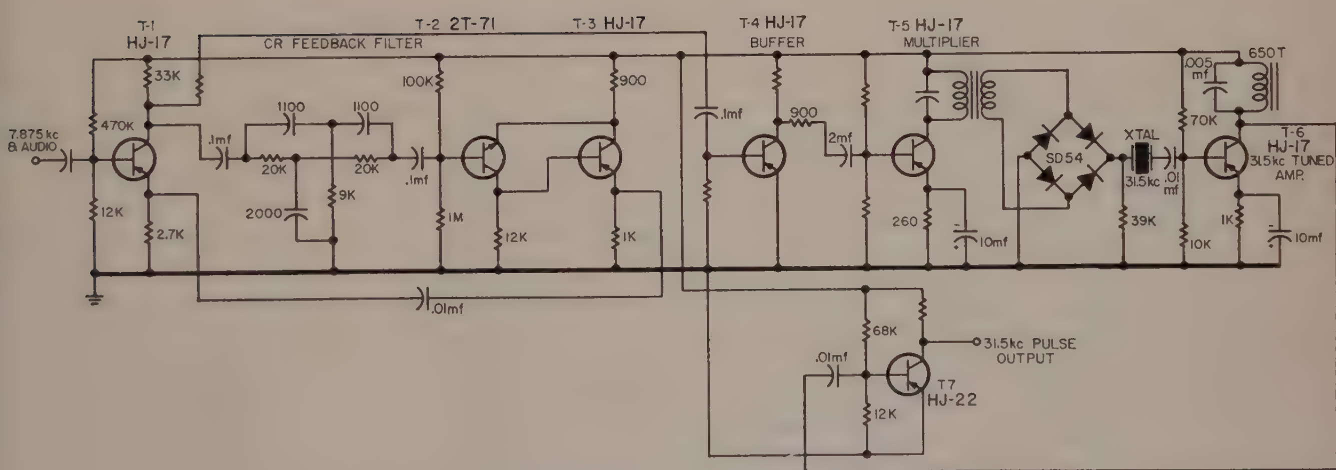

Fig. 6—Schematic diagram of 7.875 *kc* ($f_h/2$) separator.

Fig. 6 consists of the *RC* parallel T circuit and the feedback loop *T2* and *T3*.

Due to transistorization, the size of the frequency separator has been reduced to as small as 70 x 25 mm. The 7.875 *kc* sine wave sync signal multiplies its frequency four times and drives the *afc* circuit through the 31.5 *kc* crystal filter. The schematic diagram of the *afc* circuit is shown in *Fig. 7*. The operation of this circuit is analogous to that of the corresponding electron tube circuit.

The output of the bridge, consisting of diodes *D1, D2, D3*, and *D4*, is a *d-c* signal corresponding to the phase difference between the PCT sync and the external sync. This detected signal drives the reactance transistor *T6* and controls the frequency of the master oscillator *T7* to achieve minimal phase difference. The reactance transistor *T6* is an inductance element and its equivalent inductance is 50 *mh*.

Series type regulators are used for the power source. One is shown in *Fig. 8*, in which *T1* is a series

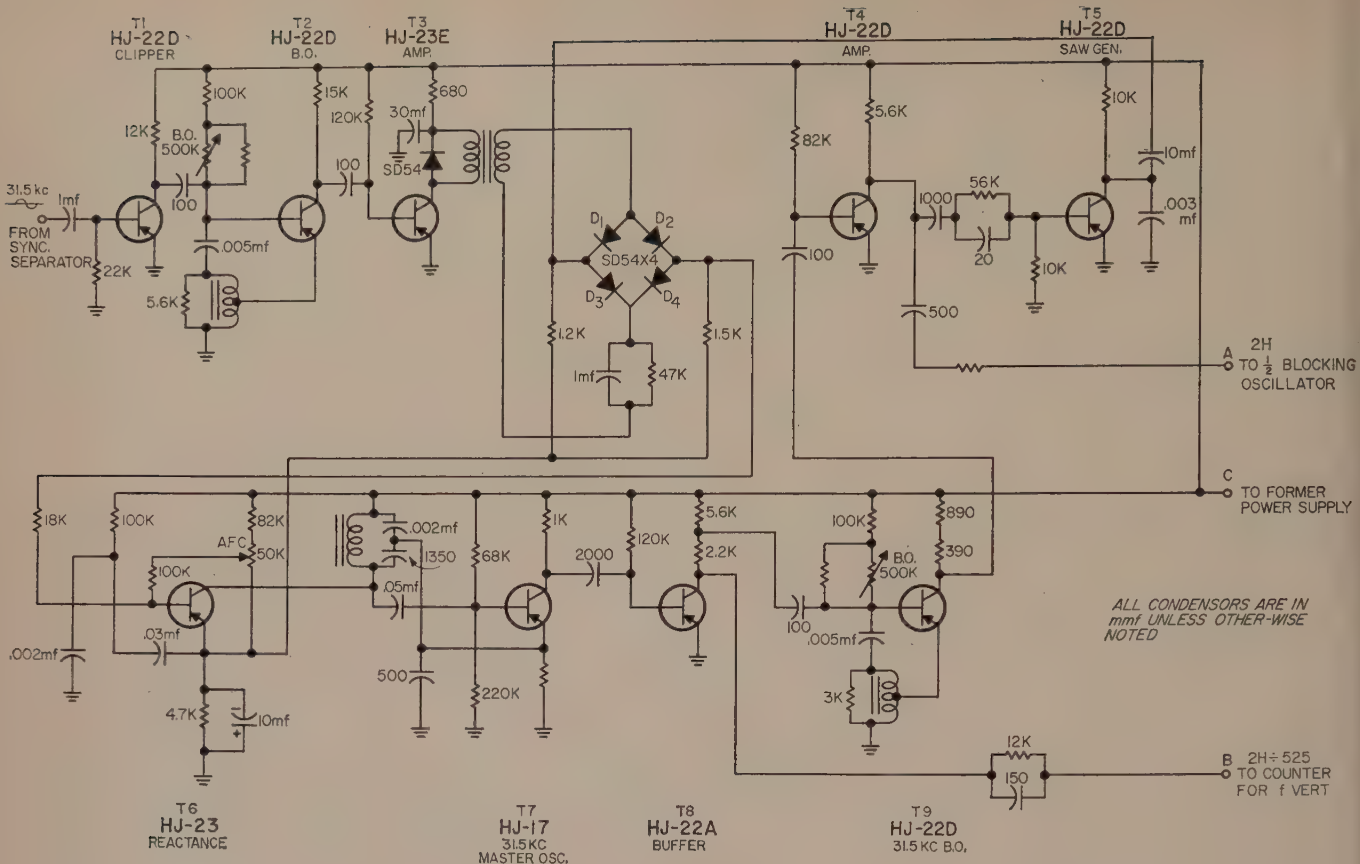

Fig. 7—Schematic diagram of *afc* circuit.

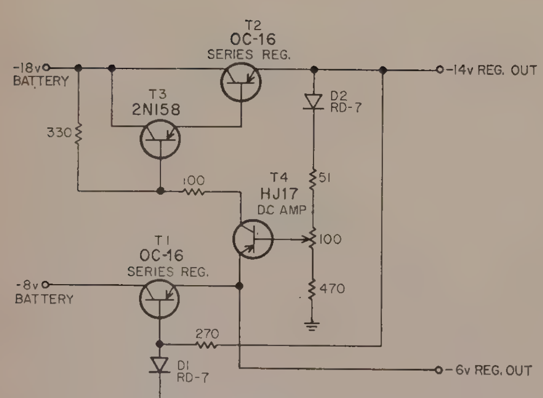

Fig. 8—Schematic diagram of series regulator.

TABLE I—Interchangeability Chart

Japanese Transistor	Class of Service	Replace by EIA Type
HJ17	Audio Amp	2N34, 2N37, 2N217
HJ22D	IF Amp	2N78, 2N135, 2N218
HJ23E	Convertor	2N219, 2N172, 2N252
HJ32	HF Amp	2N247, 2N274, 2N370
HJ55	Switching	2N219, 2N172, 2N252
2N158	Audio power	2N158
2N301	Audio power	2N301
2T51	HF Amp	(NPN)—HJ22D
2T71/HJ30	HF Amp	(NPN)—HJ23E
OC16	Audio power	

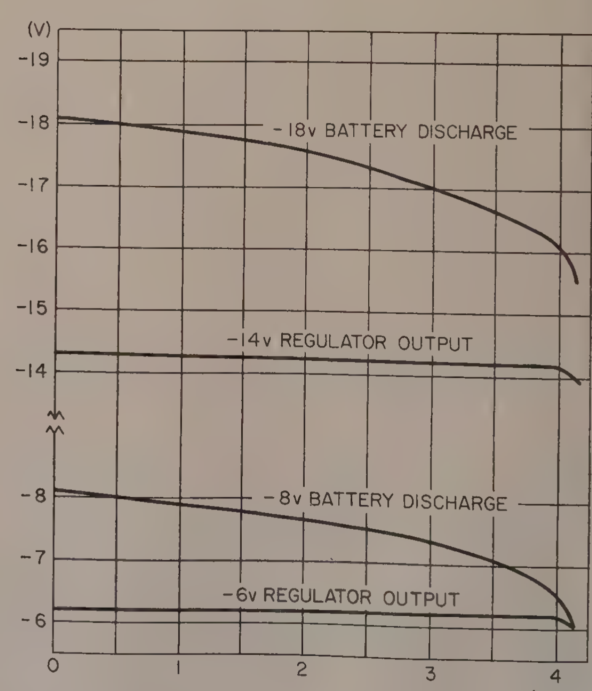

Fig. 9—Battery discharge and regulation curves.

regulator for $-6v$; $T2$ and $T3$ are for $-14v$; $T4$ is a feedback amplifier; and $D1$ and $D2$ are silicon reference diodes.

The overall discharge curve of the PCT in *Fig. 9* shows that the voltage drop becomes less than on the order of 10^{-3}.

The variations of the filament voltage and of the electrode voltage of a 1-inch vidicon and that of the pencil tube are so small and the stability during operation is so high that once the equipment is set, the cameraman simply has to control the optical focus and the lens iris.

The power consumption of PCT is 36 watts.

The base station contains a camera control unit (CCU), which is the same as the usual image-orthicon CCU in size, and a 2000 *mc* microwave receiving head including a 150 *mc fm* transmitter and antennas. (See *Fig. 10.*)

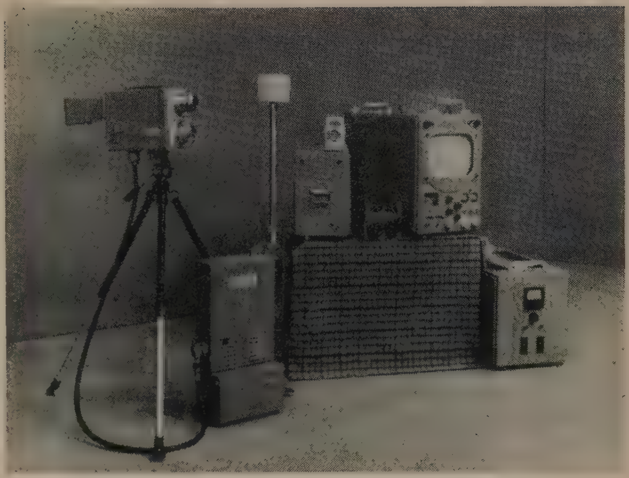

Fig. 10—Portable camera-transmitter and base station equipment.

The camera control unit of PCT is usually set and operated with other image-orthicon cameras in the vehicle designed for remote pickup.

(To be continued)

Applications Engineering Digests

APPLICATIONS ENGINEERING DIGEST NO. 36

Thermistors and Varistors; Victory Engineering Corp., Union, New Jersey.

Background of Thermistors

The basic characteristics of semiconductors were discovered and investigated over one-hundred years ago. As early as 1834, Michael Faraday noted and recorded the high "negative temperature coefficient of resistance" of certain semi-conductors. His discovery was nothing more than a curiosity at that time.

Work with temperature sensitive elements progressed very slowly for many years due to the difficulty of producing units with high stability. It was only in recent years, after extensive research and development work had been undertaken, that a satisfactory product was produced. World War II uses provided industry with its first sizable production volume and only since that time has the introduction of many and varied commercial applications of these new and versatile units been possible.

Some Typical Uses of Thermistors

Temperature Measurement

Since the resistance of a thermistor is an exact and reproducible function of the temperature, it makes it an ideal device for temperature measurement purposes.

The large change in resistance with temperature change enables the associated use of relatively simple indicating equipment where precision measurement is not required.

Figure 36.1 shows how automobile manufacturers use a simple series connection of a thermistor and a heated bi-metal indicator gauge to replace the older liquid-operated engine temperature device.

High precision measurements can be made with a bridge type circuit as shown in *Fig. 36.2.* High resistance thermistors may be used so that the bridge leads do not affect the readings. This is an advantage over thermocouples which require special compensating leads and cold junction compensation. Two thermistors may be used in adjacent arms of a bridge to indicate temperature differentials as in very accurate calorimetric work.

Temperature Control

The use of thermistors to control temperature is very closely related to their use in measurement of temperature. In industrial and scientific work, temperature control to 0.001° has been achieved with the aid of thermistors as shown in *Fig. 36.3.* The ease with which the operating point may be adjusted in a thermistor bridge is one of the outstanding features. Such a bridge is suitable to provide a signal for extremely precise servo-type control systems.

Thermistors have found extensive use in aircraft cabin temperature and de-icing controls, domestic heating sys-

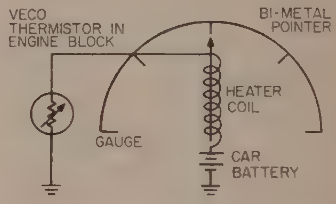

Fig. 36.1—Automobile temperature gauge.

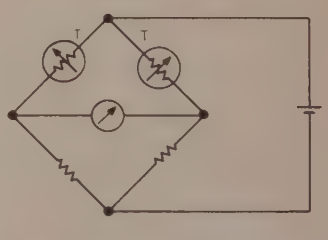

Fig. 36.2—Bridge-type measurement.

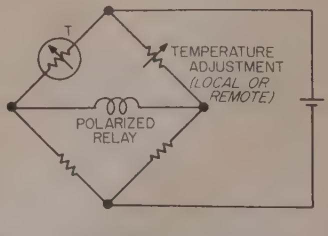

Fig. 36.3—Thermistor control circuit.

tems, refrigeration, food processing, etc. A bridge circuit using two thermistors may be used to control the indoor temperature and at the same time anticipate the amount of heat required by observing the outdoor temperature—thus preventing excessive lags in the heat supply due to changing outdoor temperature.

Transmission Circuit Elements

One of the most important uses of thermistors is in the transmission equipment field. They are used for such purposes as volume limiters, voltage regulators, compressors and expanders, automatic gain regulators, overload protectors, and oscillator amplitude stabilizers.

In the case of voltage regulators and volume limiters, thermistors may be used to stabilize output voltage in circuits where there is a considerable range of input voltages. If a suitably chosen value of resistance is placed in series with a thermistor, the voltage across the combination can be maintained almost completely independent of the current over a wide region of values. This principle finds useful application in the voltage regulation of alternating or direct current power supplies where thermistors provide regulation with negligible distortion. A simple circuit, shown in *Fig. 36.4*, illustrates this basic principle.

In volume limiter devices, the same principle is used to provide a constant or limiting value of output voltages over a specific working range thus enabling thermistor volume regulators to accommodate large volume changes without producing wave form distortion. Audio frequency speech circuits so designed have important advantages over other devices in use. Other uses are for compressors and expanders, automatic gain regulators, overload protection and oscillator amplitude stabilizers.

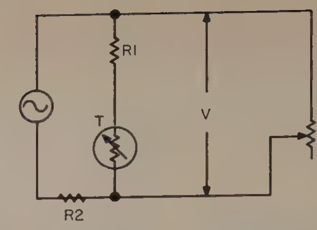

Fig. 36.4—Thermistor regulating circuit.

APPLICATIONS ENGINEERING DIGEST NO. 37

Fast Pulse Response Measurements Using an Oscilloscope; Lansdale Tube Co., Lansdale, Pa.

Purpose

The purpose of this project was to construct a graph of apparent *vs.* actual rise time of commonly used high speed oscilloscopes in order to simplify fast pulse response measurements.

Theory

The equation governing the rise time that is read on an oscilloscope is given by:

$$X^2 = a^2 + b^2 \quad (1)$$

where X is the apparent rise time that is read on the oscilloscope,
a is the rise time combination of the oscilloscope and the plug-in amplifier.
b is the actual rise time of the pulse being measured.

Solving for "b" gives the expression:

$$b = \sqrt{X^2 - a^2} \quad (2)$$

Procedure

As an example, assume that an apparent rise time of 25 millimicroseconds is read on a Tektronix type 541 oscilloscope, using a plug-in preamplifier type

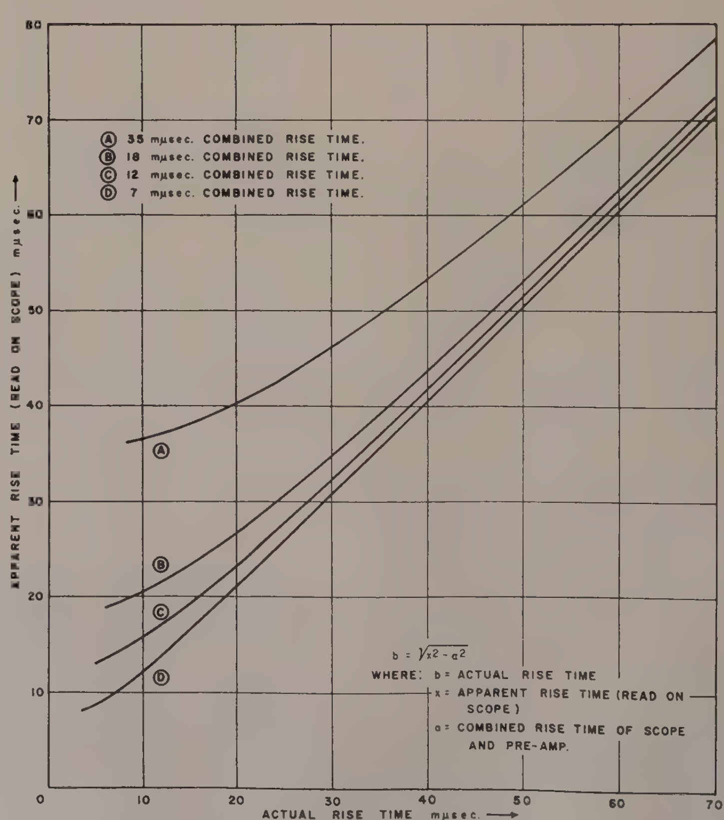

Fig. 37.1—Actual rise time vs. Apparent rise time as read on oscilloscope.

53/54C. The actual rise time can be calculated as follows:

a, from the manufacturer's specifications is given as 15 millimicroseconds,

Using Equation (2):

$$b = \sqrt{X^2 - a^2}$$

Substitute the known values:

$$b = \sqrt{625 - 225}$$

$$b = \sqrt{400}$$

$$b = 20 \text{ millimicroseconds}$$

It can now be seen that the actual rise time of the pulse being measured is 5 millimicroseconds faster than the apparent rise time.

TABLE I

Oscilloscope	Plug-In Preamplifiers		
	53/54A	53/54C	53/54K
Type 541,545	0.018 μsec	0.015 μsec	0.012 μsec
Type 531, 535 536	0.035 μsec	0.035 μsec	0.031 μsec

The rise time specifications of some commonly used oscilloscopes and pre-amplifiers combinations are given in Table I.

(*Circle 199 on Reader Service Card*)

APPLICATIONS ENGINEERING DIGEST NO. 38

The Use of Silicon Junction Diodes for the Protection of A-C and D-C Meter Circuits; Pacific Semiconductors Inc., Culver City, Calif. (P. G. Ducker)

Overload Protection

It is an established fact that sensitive low range *a-c* and *d-c* instruments can be easily damaged when their meter movements are subjected to overloads, on the order of three to four times the rated full scale deflection. This problem has been solved in the past partly by the application of thermal, or similar devices, which inherently require a trip and/or reset time.

It has been found that silicon diodes lend themselves ideally to this problem of overload protection. Being passive devices, they have an instantaneous action and do not have a reset time. As will be described in the following sections, either the non-linear characteristics of a forward biased diode, or the Zener region of a reverse biased diode may be used.

Protection of D-C Microammeters

Most microammeters with a full scale deflection of 50 μa, have an internal resistance of 2000 ohms. This represents a full scale deflection of 0.1 volts. Since we want the diode to conduct as soon as possible to carry the excess current, a resistance R_s is used in series with the meter to increase the terminal voltage to almost that of the conduction voltage of the diode. This circuit is shown in *Fig. 38.1* illustrating a Model 27 Simpson microammeter with a full scale deflection of 50 μa and internal resistance R_M of 200 ohms. The value of R_s is found from the following equation:

$$R_S = \frac{E_f}{I_M} - R_M$$

where I_M = Full scale deflection of the microammeter, in amps.
R_M = Internal resistance of meter, in ohms.
E_f = Point of beginning conduction of diode, typically 0.3 volts.

Then for our example,

$$R_S = \frac{0.3}{50 \times 10^{-6}} - 2000 = 4000 \text{ ohms}$$

Protection of D-C Voltmeters Use of Diode Forward Characteristics

The 50 microampere meter discussed in the previous section can be adapted to a 20,000 ohm/volt voltmeter by the addition of suitable voltage multiplier resistors. The circuit is illustrated in *Fig. 38.2*.

Use of Zener Diodes to Expand the Scale of D-C Microammeters and Low-Range Milliammeters

It is sometimes necessary to obtain measurements of voltage over a limited range. Zero suppressed instruments are used for this application. This means that all voltages below a certain value applied to the meter will not cause any movement of the pointer. The meter is calibrated so that the lowest voltage value takes the place of the conventional zero.

The Zener diode can be utilized for zero suppression as shown in *Fig. 38.3*. The Zener diode voltage determines the threshold voltage of the meter, and the voltage multiplier resistance determines the full scale deflection.

Since the voltage scale is non-linear, it is necessary to calibrate the meter scale against some known standard.

(*Circle 200 on Reader Service Card*)

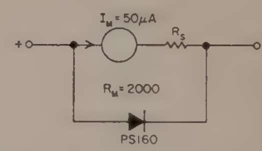

Fig. 38.1—D-C microammeter protection.

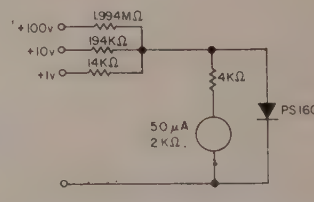

Fig. 38.2—D-C voltmeter protection.

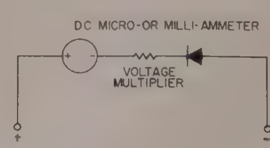

Fig. 38.3—Zener diode for scale expansion.

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Annealing of Radiation Damage in Semiconducting Devices	U S Govt Res Reports September 11 1959 LC $7.80 PB 140729	Experiments to determine the effects of radiation upon silicon carbide diodes.	V. E. Bryson
Application of PNPN Triodes to Magnetic Core Memories	U S Govt Res Reports September 11 1959 LC $7.80 PB 140728	A shunt current pulser using trinistors (p-n-p-n triodes) appears promising as an efficient driver. Trinistors have two states ON (low Z) and OFF (high Z).	A. Doty
Design of a Triple-Gated-Coincidence Summing Circuit	U S Govt Res Reports September 11 1959 LC $13.80 PB 140730	Introduction and outline of the ionization chamber as a source of input to the proposed circuit. The design approach is explained.	D. B. Harris
An Experimental Semiconductor-Diode Parametric Amplifier at S-Band Frequencies	U S Govt Res Reports September 11 1959 LC $15.30 PB 140922	A parametric amplifier was constructed which used a 1N263 diode as a nonlinear reactance element. The signal frequency was near 2800 *mc* and the pumping frequency near 5600 *mc*.	J. V. Boone
The Hall Generator as an Analog Multiplier	U S Govt Res Reports September 11 1959 LC $7.80 PB 140942	Accuracies of 1% of full scale can easily be attained. This anticipates that a further study of the error problem will materially improve accuracy.	F. H. Miller
Engineering Services on Transistors	U S Govt Res Reports September 11 1959 LC $12.30 PB 139660	Optional measurements of vapor adsorption on silicon microwave transistor. Boron diffusion by means of a boron trichloride source.	R. J. Archer H. H. Loar Et al
Statistical Plan for the Transistor Inter-Laboratory Experiment	U S Govt Res Reports September 11 1959 LC $3.30 PB 139516	The object was to determine if the three laboratories participating in this test agreed substantially with respect to them mean level of six test parameters.	A. Lieberman
Research & Development "Alpha-Greater-Than-One" Silicon Devices	U S Govt Res Reports September 11 1959 LC $4.80 PB 137062	A proposal for achieving a negative resistance diode structure based on point contact transistor action.	CBS-Hytron
Investigation of Microwave Duplexer Switching Mechanisms	U S Govt Res Reports September 11 1959 LC $6.30 PB 140807	Experiments were performed to determine the free electron removal processes in water vapor, in mixtures of water vapor in helium, or argon gasses alone.	A. A. Dougal K. Rose S. Takeda
Final Engineering Report	U S Govt Res Reports September 11 1959 PB 139508 LC $16.80	Experiments with materials arsenic doped silicon, electron-irradiated sodium nitrate and electron-irradiated calcite for two-level solid-state maser use have been performed.	J. L. Burkhardt M. S. Cohen H. J. Okoomian
Radio Chemistry Section, Components & Techniques Laboratory	U S Govt Res Reports September 11 1959 LC $7.80 PB 140826	The report describes the work performed on the studies of a void zone purification apparatus for purifying silicon tetraiodide, and the decomposition of this material to silicon.	C. D. Turner
Solid State Diffusion	U S Govt Res Reports September 11 1959 LC $4.80 PB 140824	A method for making junctions in silicon by solid state diffusion is presented. Employs a fused silica tube extended through two controlled temperature zones.	I. Berman
Ohmic Contacts and Preliminary Conductivity Measurements on Cadmium Sulphide Whiskers	U S Govt Res Reports September 11 1959 LC $12.30 PB 140929	A method is developed for handling and putting electrical contracts on Cadmium sulfide whisker crystals. Sputtered platinum contacts are found to have an ohmic response on cadmium sulfide whiskers.	G. K. Hendricks
Research Directed Toward the Investigation of Silicon and Silicon Carbide Surfaces	U S Govt Res Reports September 11 1959 LC $3.30 PB 140823	Silicon Carbide surfaces cleared in ultra high vacuum by argon-ion bombardment 1000° C heating absorbs oxygen at room temperature with a sticking coefficient of the order of 0.01.	J. A. Dillon Jr. R. M. Oman
Lattice Specific Heats Near 0 Degrees K with an Application to Germanium	U S Govt Res Reports September 11 1959 LC $6.30 PB 140900	Formulas for the low temperature lattice specific beat are developed on the basis of the general adiabatic and harmonic assumptions, independently of special models or numerical procedures.	P. M. Marcus A. J. Kennedy
Investigation of the Surface States on N-Type Germanium	U S Govt Res Reports September 11 1959 LC $15.30 PB 137271	The studies of semiconductor surface phenomena over the past few years has developed a surface model which postulates the existence of two types of surface states separated by a thin layer of oxide.	R. C. Sirrine
Oxygen Impurity in Silicon Single Crystal	U S Govt Res Reports September 11 1959 LC $3.30 PB 137134	Comparison of the lattice constant and density of "pure" silicon crystal and oxygen contaminated crystal favors the substitutional position of oxygen on the silicon lattice rather than the interstitial.	A. Smakula J. Kalnajs
Studies on the Mechanism of Electroluminescence	U S Govt Res Reports September 11 1959 LC $9.30 PB 139585	Digests coverage to date in the form of listings, reports, and papers previously submitted on the subjects. Also new material involving variable frequency and electroluminescent powders as semiconductors.	A. Lucyckx J. Vandewavwer Et al
Electronic Properties of Semiconductor Materials	U S Govt Res Reports September 11 1959 LC $6.30 PB 137070	The lifetime of minority carriers injected either from point-contracts on p-type silicon increases with an increase in temperature above room temperature.	J. Maczuk R. M. Showers B. P. Fabricand
Industrial Preparedness Study on Diffused Semiconductor Devices 5 and 9	U S Govt Res Reports September 11 1959 LC $3.00 PB 137162	Techniques and modification for fabricating germanium devices to meet the requirements per SD project 509-77 (PROP) for Devices 5 & 9 have been developed.	Motorola, Inc.
Characteristics of Photoconductive Detectors	U S Govt Res Reports September 11 1959 OTS $.75 PB 151728	A description of the basic characteristics of photoconductive detectors is given to aid in the interpretation of data obtained in photoconductive research and experimentation.	A. J. Cussen

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Dec. 10, 1957 to Jan. 14, 1958. In subsequent issues, patents issued from Oct. 15, 1957 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

December 10, 1957

2,815,608 Semiconductor Envelope Sealing Device and Method—L. C. Thompson, Jr. Assignee: Hughes Aircraft Co. The apparatus and method with which a resilient electrode may be placed in electrical contact with the surface of a semiconductor body to provide reproducible electrical characteristics.

2,815,179 Transistor Push-Pull Amplifier—R. Gittleman, J. Tellerman. Assignee: American Bosch Arma Corp. A circuit in which two similar type junction transistors are connected in push-pull combination to provide a Class A circuit operating from a single ended source.

2,816,220 Frequency Converter—H. C. Goodrich. Assignee: Radio Corporation of America. A semiconductor frequency converter in which the oscillatory wave is developed without utilizing an external feedback path said converter providing substantial conversion power gain.

2,816,228 Semiconductor Phase Shift Oscillator and Device—H. Johnson. Assignee: Radio Corporation of America. A device comprising a body of semiconductor material having alternate zones of opposite conductivity type, a semiconductor delay line integral with one of these zones, said delay line including a plurality of series connected filaments of semiconductor material and *p-n* junction portions.

2,816,230 Blocking Oscillator Circuit—J. E. Lindsay. Assignee: Radio Corporation of America. A blocking oscillator circuit comprising a transistor, regenerative feedback means between the collector and base electrodes, a rectifying device connected with the emitter, and a time-constant network for the circuit connected with the rectifying device.

2,816,232 Germanium for Infra Red Detector—E. Burstein. Assignee: United States of America (Navy Department). A device for detecting long infra-red radiation, said device consisting of a specimen of germanium having a zinc impurity concentration between 10^{13} and 10^{18} atoms of zinc per cubic centimeter, means for maintaining the specimen at temperatures near O°K., and means for determining the energy level of the specimen.

2,816,234 Radiant Energy Detector—S. G. Ellis. Assignee: Radio Corporation of America. A method for the detection of radiant energy comprising the orientation of a photosensitive crystal such that the glancing angle of incident radiation is the Bragg Angle and recording a change in a physical characteristic of said crystal in response to said radiant energy.

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

2,816,237 System for Soupling Signals Into and Out of Flip-Flops—D. H. Hagerman. Assignee: Hughes Aircraft Co. A system adapted to couple signals into and out of a transistor flip-flop and which will allow a single slip-flop to supply intelligence signals simultaneously to 25 or 30 gates.

2,816,238 Electronic Switches—G. Elliot. Assignee: General Dynamics Corp. An electronic switch comprising a semiconductive device having first and second junctions in series with the circuit to be closed, said switch being actuated by application of suitable potentials to a control electrode of the semiconductor device.

2,816,260 Regulated D.C. Power Supply—D. G. Scorgie. Assignee: United States of America (Navy Dept.). A voltage regulator comprising two full wave magnetic amplifiers having two cores saturated alternately upon successive half cycles of an alternating voltage, and a control circuit including a diode that is poled so that current will flow when the zener breakdown voltage is exceeded.

2,816,283 Semiconductor Null Detector—M. C. Steele. Assignee: Radio Corporation of America. A null detector comprising a semiconductor double diode in which a pair of zones of one conductivity type is separated by, and contiguous with, a zone of the opposite conductivity type; and in which the middle zone can be greater than the diffusion length of the carriers of the semiconductor.

December 17, 1957

2,816,847 Method of Fabricating Semiconductor Signal Translating Devices—W. Shockley. Assignee: Bell Telephone Laboratories. A method of producing a semiconductive body having a zone of conductivity type opposite to that of the bulk of the body, said method consisting of applying to one face of a germanium or silicon body a coating of conductivity type determining impurity, directing an electron beam against said coating to effect diffusion of said impurity into the material, and forming a predetermined configuration of opposite conductivity type upon said surface.

2,816,850 Semiconductive Translator—H. E. Naring, Assignee: Bell Telephone Laboratories. A means of inhibiting the formation of deleterious leakage paths in semiconductor devices of the junction type.

2,816,964 Stabilizing Means for Semiconductor Circuits—L. J. Giacolletto. Assignee: Radio Corporation of America. A translating circuit in which the emitter current of a stabilized transistor is maintained at a constant value despite circuit or environmental changes.

2,817,046 Filament Bar Casing and Method of Making Same—S. I. Weiss. Assignee: None. A casing for a filament bar of semiconductive material comprising a cup shaped glass housing having a mouth, a glass member, a cavity defined between the base member and the casing, a metal member embedded in solidified powdered glass and extending around the cavity, a pair of holders in the housing and a bar of semiconductor material positioned at its ends on said holder.

2,817,047 Dry Contact Rectifiers—E. A. Richards, L. J. Ellison. Assignee: International Standard Electric Corp. A selenium rectifier assembly comprised of rectangular plates pierced with a row of holes along each major edge, and means for stacking a number of plates with intervening spacing and electrical bus bars between parallel pairs of edges of each adjacent pair of plates.

2,817,048 Transistor Arrangement—E. Thuermel, K. Sieberty, H. Henker, D. Enderlein. Assignee: Siemens and Halske Aktiengessellschaft (Germany). A transistor arrangement comprising a casing, an electrode in good heat conducting connection thereto, an insulating layer between the transistor and the casing, said layer forming the dielectric of a capacitor, said casing forming one coating of said capacitor, and a metallic part forming the other coating of the capacitor.

2,817,057 Resistive Reactor—H. E. Hollman. Assignee: None. A device that utilizes a nonlinear impedance to control currents over a wide frequency range.

December 24, 1957

2,817,607 Method of Making Semiconductor Bodies—D. A. Jenny. Assignee: Radio Corporation of America. A method of forming a *p-n* rectifying junction within a semiconductor body by diffusion of an impurity-yielding material into the body at a temperature below the melting points of both the body and the impurity yielding material.

2,817,608 Melt-Quench Method of Making Transistor Devices—J. I. Pankove. Assignee: Radio Corporation of America. A method of making semiconductor devices by melting a longitudinal portion of a crystalline semiconductive filament, maintaining another longitudinal portion of

said filament in its solid state, and quenching the melted portion by refreezing at a cooling rate of at least 500°C per second so that solidification starts at the unmelted cool end and proceeds to the other end, thus forming a pair of spaced parallel p-n rectifying barriers.

2,817,609 Alkali Metal Alloy Agents for Auto-Fluxing in Junction Forming—W. P. Waters. Assignee: Hughes Aircraft Co. A method of fusing a metal alloy pellet to a region of an active impurity-doped semiconductor starting crystal, said alloy acting as its own fluxing agent.

2,817,613 Semiconductor Devices with Alloyed Conductivity-Type Determining Substance—C. W. Mueller. Assignee: Radio Corporation of America. A device having at least two p-n junctions in which the conductivity of the materials between the junctions is greater in an area adjacent to one junction than in an area adjacent to the other junction, and in which said junctions have different characteristics.

2,817,715 Amplifier Circuit Having Linear and Non Linear Amplification Ranges—F. G. Blake. Assignee: California Research Corp. Means for suppressing the peaks of a voltage wave entering an amplifier and means for expanding the peaks at the output to reproduce the wave shape.

2,817,761 Transistor Oscillator Circuits—H. E. Hollman. Assignee: None. A transistor oscillator including a transistor that exhibits non-linear transfer characteristics in response to a periodically varying applied voltage, and means for feeding back a portion of the oscillatory energy developed by a resonator, said feed-back occurring in a nonlinear fashion.

2,817,771 Pulse Height Discriminator—J. M. Barnothy. Assignee: Research Corp. A discriminator unit that may be transferred between the highest and lowest channel of an amplitude channelizer without requiring alteration or calibration.

2,817,772 Pulse Switching Apparatus—W. S. Lee. Assignee: United States of America (Navy Dept.). Apparatus having a single input and a plurality of outputs selectively controlled by a plurality of crystals, one of which is permitted to pass the input signal to its respective output in accordance with a switch position selected by a remotely placed switch.

2,817,797 Rectifier—W. J. Coyle. Assignee: United-Carr Fastener Corp. A hermetically sealed rectifier assembly which has internal spring means bearing rectifier plates into position and completing an electric circuit thereto.

2,817,798 Semiconductors—D. A. Jenny. Assignee: Radio Corporation of America. A device consisting of a single crystal body of an alloy of germanium and at least 1% semiconducting silicon, and at least one rectifying electrode connected to said body.

2,817,799 Semiconductor Devices Employing Cadmium Telluride—D. A. Jenny. Assignee: Radio Corporation of America. A device comprising a body of semiconductive cadmium telluride having a p-type region, the conductivity of which is determined by trace amounts of impurity centers of the atoms of at least one element of group IIIa and Va of the periodic system.

December 31, 1957

2,818,361 Heat Treatment of Silicon Transistor Bars—R. E. Anderson, W. L. Medlin. Assignee: Texas Instruments. A method of making transistor bars by forming a grown silicon junction bar having an n-type antimony-doped collector portion, a thin p-type aluminum doped base portion, an n-type arsenic doped emitter portion; and heating said bar to about 500°C for a period between 15 minutes and two hours.

2,818,470 Compensated Transistor Circuit—A. Busala, L. A. Meacham. Assignee: Bell Telephone Laboratories. A transistor circuit that maintains the transmission level of a plurality of telephone subscribers substantially constant regardless of the loop length and the range of loop currents.

2,818,531 Electroluminescent Image Device—S. C. Peek, Jr. Assignee: Sylvania Electric Products, Inc. An image producing device comprising an electroluminescent phospor layer, a series of conducting lines on one side of said layer, another series of lines on the opposite sides of the layer and at an angle to the first set of lines, and a rectifier connected to each of the lines in at least one of said series.

2,818,536 Point Contact Semiconductor Devices and Methods of Making Same—J. N. Carman, Jr., E. E. Maiden. Assignee: Hughes Aircraft Co. In a point contact device, a whisker element comprising a resilient molybdenum wire pointed at one end, and a layer of elemental indium plated over the pointed end.

2,818,537 Germanium Diodes—H. Wolfson. Assignee: International Standard Electric Corp. A crystal rectifier comprising a crystal of germanium, a low-resistance-contact base electrode, a thin contact film of an alloy of germanium and lead or tin, said film covering a part of the crystal surface, and a catwhisker electrode making contact with said film.

January 7, 1958

2,819,191 Method of Fabricating a P-N Junction—C. S. Fuller. Assignee: Bell Telephone Laboratories. A method of producing stable p-type silicon which comprises heating said material to between 350 and 500°C for 1 to 48 hours and then heating said material to between 900 and 1300°C for more than 15 hours.

2,819,352 Transistor Magnetic Amplifier Circuit—C. B. Houck, Jr. Assignee: General Precision Laboratories, Inc. An amplifier comprising an n-p-n junction transistor and a p-n-p junction transistor, having their connector electrodes connected to opposite terminals of a potential source, a pair of saturable core reactors, and a signal input circuit connected between a common emitter terminal and the base electrodes of said transistors.

2,819,414 Radio Active Battery Employing Stacked Semiconducting Devices—R. L. Sherwood, P. Rappaport. Assignee: Radio Corporation of America. A primary source of electrical energy comprising a plurality of aligned spaced junction type semi-conducting devices, an electrically conductive plastic between adajcent devices, and a radioactive source positioned to irradiate all of said devices so as to generate a potential.

2,819,433 Selenium Rectifiers and the Method of Making the Same—C. Scudder. Assignee: Syntron Co. A selenium rectifier comprising a conducting sheet having approximately fifty or more very thin superimposed layers of crystalline selenium, a blocking layer on the topmost selenium layer, and a counter electrode on the blocking layer.

2,819,434 Rectifier Stack—M. J. Mattheyses. Assignee: International Telephone and Telegraph Company. A rectifier assembly having several elements and several spaced cooling fins, the latter being arranged so that a rectifier element mounted on one fin protrudes through an opening in the adjacent fin.

2,819,436 Method of Making Dry Contact Rectifiers, Particularly Selenium Rectifiers—H. A. Bartels. Assignee: International Standard Electric Corporation. A rectifier comprising a base electrode, a semiconductive layer, and a counter electrode consisting of a nonconductive lacquer having distributed small metal particles therein, said particles constituting a multipoint rectifier through a barrier layer formed by the non-conductive lacquer.

January 14, 1958

2,819,513 Semiconductor Assembly and Method—S. T. Martin. Assignee: None. A method of mounting semiconductors on bases by interposing separating pins between the individual members of a cluster of base pins to provide a configuration of four-fold symmetry and fastening a semiconductor sheet to the ends of said base pins.

2,819,990 Treatment of Semiconductive Bodies—C. S. Fuller, H. Reiss. Assignee: Bell Telephone Laboratories. A semiconductor device comprising a germanium body having one portion which includes lithium and an acceptor impurity whose ions have a plural negative charge in germanium, said acceptor forming stable ion-pair bonds with the lithium.

2,820,135 Method For Producing Electrical Contact to Semiconductor Devices—K. A. Yamakawa. Assignee: Pacific Semiconductors, Inc. A method consisting of bringing the end of a whisker element into contact with a body of solid solder, passing a current through said whisker to weld said whisker to said body, and welding the whisker with the body of solder attached thereto to a semiconductor crystal.

2,820,143 Transistor Phase Detector—G. O. D'Nelly N. B. Fjeldsted. Assignee: Hughes Aircraft Company. A transistor phase detector for producing direct current voltage levels in response to the phase relationships between applied reference and comparison signals.

2,820,145 Transistor Oscillator Circuit Arrangement—E. Wolfendale. Assignee: North American Phillips Company, Inc. In a transistor circuit, a transistor driven at a frequency so high that a phase displacement occurs between the base current and the emitter current so that the base input impedance has negative resistance component.

2,820,151 Parallel Magnetic Complementers—W. F. Steagall. Assignee: Sperry Rand Corporation. An input circuit and energy source for providing complementing action in parallel magnetic amplifiers.

[To Be Continued]

CHARACTERISTICS CHART of NEW TRANSISTORS

Announced Between Nov. 1, 1959 and Dec. 31, 1959

This is a partial listing and will be continued in the April issue.

MANUFACTURERS (In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AEG— Allgemeine Elecktricitats-gesellschaft
AMP— Amperex Electronic Corp.
AEI— Associated Electrical Industries LTD. and Siemens Edison Swan.
BEN— Bendix Aviation Corp.
BOG— Bogue Electric Mfg. Co.
CBS— CBS-Electronics
CRY— Crystalonics, Inc.
CSF— Compagnie Generale
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
FSC— Fairchild Semiconductors Corp.
FTHF— French Thomson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GEM— Great Eastern Mfg. Co.
GTC— General Transistor Corp.
HSD— Hoffman Semiconductor Div.
HUG— Hughes Aircraft Co.
HIVB— Hivac Ltd.
IND— Industro Transistor Corp.
LCTF— Labortoire Central de Telecommunications
MIFI— Microfarad (Italy)
MIN— Minneapolis-Honeywell Regulator Co.
MOT— Motorola, Inc.
MUL— Mullard Ltd.
NAC— National Semiconductor Corp.
NTLB— Newmarket Transistors Ltd.
PSI— Pacific Semiconductors, Inc.
PHI— Philco Corp., Landsdale Tube Co.
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
RHE— Rheem Semiconductor Corp.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SONY— Sony Corp.
SPE— Sperry Gyroscope Co.
SPR— Sprague Electric Co.
SYL— Sylvania Electric Products Inc.
STCB— Standard Telephone & Cables, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments
TIIB— Texas Instruments Ltd.
TUN— Tung-Sol Electric, Inc.
UST— U. S. Transistor Corp.
WEC— Western Electric Co., Inc.
WEST— Westinghouse Electric Corp.

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

GENERAL TRANS.: 2N327A, 2N328A, 2N578 thru 2N582, 2N1025, 2N1026, 2N1034, 2N1035, 2N1090, 2N1091
MICROFARAD: This company is licensed by Compagnie Generale de T.S.F. and manufactures all types produced by Compagnie Generale de T.S.F.
MOTOROLA: 2N705, 2N710
NATIONAL SEMI.: 2N560, 2N696, 2N697, 2N702, 2N703, 2N715, 2N716, 2N1060, 2N1234
RAYTHEON: 2N395, 2N396, 2N397, 2N1090, 2N1091
SYLVANIA: 2N404, 2N417, 2N428, 2N644, 2N1000, 2N1302, 2N1304, 2N1306, 2N1308

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics	Gain		MFR. See code at start of charts
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	PARAMETER and (condition)	VALUE	
2N377A	5	NPNA	Ge	150	.50	40	40	6.0	h_{FE}:I_C- 30ma	40	SYL
2N385A	5	NPNA	Ge	150	.50	40	40	7.0	h_{FE}:I_C- 30ma	70	SYL
2N388A	5	NPNA	Ge	150	.50	40	40	8.0	h_{FE}:I_C- 30ma	90	SYL
2N695	5	PNPMe	Ge	75	1000	15	15	250†	h_{FE}:	40	MOT
2N698	3,4,5	NPNMe	Si	2000	75	120	80	180	h_{FE}:I_C-150ma	30Ø	FSC
2N700	2	PNPMe	Ge	75	1000	25	20		h_{fe}:	10	MOT
2N707	3,4,5	NPNMe	Si	1000	150	56	28	400	h_{FE}:I_C- 10ma	12Ø	FSC
2N717	3,4,5	NPNMe	Si	1500	100	60	40	150	h_{FE}:I_C-150ma	40Ø	FSC
2N718	3,4,5	NPNMe	Si	1500	100	60	40	150	h_{FE}:I_C-150ma	75Ø	FSC
2N728	5	NPN	Si	500		15	15	150	h_{FE}:I_C- 10ma	20min	TRA
2N729	5	NPN	Si	500		30	30	150	h_{FE}:I_C- 10ma	20min	TRA
2N741	2	Me	Ge	150	500	15	15	360†	h_{FE}:	25	MOT
2N742	5	PNPD	Si	600	210	60	60	100	h_{fe}:5.0V,100ma	35	NAC
2N745	5	D	Si	200	750	45		10	h_{fe}:I_c- 10ma	20	RAY
2N746	5	D	Si	200	750	45		20	h_{fe}:I_c- 10ma	45	RAY
2N747	5	D	Si	200	750	25	25	25	h_{fe}:I_c- 10ma	30	RAY
2N748	5	D	Si	200	750	30	30	25	h_{fe}:I_c- 10ma	20	RAY
2N749	4	D	Si	200	750	45	45	50	PG at 6.0Mc	7db	RAY
2N750	4	D	Si	200	750	50	50	25	PG at 6.0Mc	4db	RAY
2N751	4	D	Si	200	750	20	20	25	PG at 6.0Mc	2.2db	RAY

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	Gain: VALUE	MFR. See code at start of charts
2N1018	5	A	Ge	150	350	30	8.0	25	h_{FE}:I_B-1.0ma	140	RAY
2N1177	4	PNPD	Ge	80		30		140	h_{fe}:I_c-1.0ma	100	RCA
2N1178	4	PNPD	Ge	80		30		140	h_{fe}:I_c-1.0ma	40	RCA
2N1179	4	PNPD	Ge	80		30		140	h_{fe}:I_c-1.0ma	80	RCA
2N1180	4	PNPD	Ge	80		30		100	h_{fe}:I_c-1.0ma	80	RCA
2N1213	5	PNPMe	Ge	75		25	25				RCA
2N1214	5	PNPMe	Ge	75		25	25				RCA
2N1215	5	PNPMe	Ge	75		25	25				RCA
2N1216	5	PNPMe	Ge	75		25	25				RCA
2N1314	3	PNPA	Ge		1.0	32	32	.15	h_{fe}:I_E-1.0A	33	AMP
2N1315	3	PNPA	Ge		1.0	32	32	.30	h_{fe}:I_E-1.0A	64	AMP
2N1366	4	A	Ge	150	350	20	18	10	h_{FE}:I_C-1.0ma	70	RAY
2N1367	4	A	Ge	150	350	20	18	10	h_{FE}:I_C-1.0ma	70	RAY
2N1439	2	PNPA	Si	400	440	50	40	1.0	h_{fe}:6.0V,1.0ma	9.0	NAC
2N1443	2	PNPA	Si	400	440	50	30	1.0	h_{fe}:6.0V,1.0ma	70	NAC
2N1470	3	D	Si	5500	3.0	60	60	1.0	h_{fe}:I_c-1.0A	15	RAY
2N1515	4,5	PNPAD	Ge	50	600	20		70#	PG at .45Mc	35	AMP
2N1516	4,5	PNPAD	Ge	60	500	20		70#	PG at .45Mc	57	AMP
2N1517	4,5	PNPAD	Ge	70	500	20		100#	PG at 100Mc	11	AMP
2N1518	3	PNPA	Ge		.80	50	40	4KcΔ	h_{FE}:I_C- 25A	12min	DEL
2N1519	3	PNPA	Ge		.80	80	60	4KcΔ	h_{FE}:I_C- 25A	12min	DEL
2N1520	3	PNPA	Ge		.80	50	40	4KcΔ	h_{FE}:I_C- 35A	12min	DEL
2N1521	3	PNPA	Ge		.80	80	60	4KcΔ	h_{FE}:I_C- 35A	12min	DEL
2N1522	3	PNPA	Ge		.80	50	40	4KcΔ	h_{FE}:I_C- 50A	12min	DEL
2N1523	3	PNPA	Ge		.80	80	60	4KcΔ	h_{FE}:I_C- 50A	12min	DEL
2N1528	4	D	Si	150	1000	25	25	20	PG at 6.0Mc	4db	RAY
2N1529	3	PNP	Ge	90W	.80	40	30	10KcΔ	h_{FE}:	30	MOT
2N1530	3	PNP	Ge	90W	.80	60	45	10KcΔ	h_{FE}:	30	MOT
2N1531	3	PNP	Ge	90W	.80	80	60	10KcΔ	h_{FE}:	30	MOT
2N1532	3	PNP	Ge	90W	.80	100	75	10KcΔ	h_{FE}:	30	MOT
2N1533	3	PNP	Ge	90W	.80	120	90	10KcΔ	h_{FE}:	30	MOT
2N1534	3	PNP	Ge	90W	.80	40	30	8.5KcΔ	h_{FE}:	50	MOT
2N1535	3	PNP	Ge	90W	.80	60	45	8.5KcΔ	h_{FE}:	50	MOT
2N1536	3	PNP	Ge	90W	.80	80	60	8.5KcΔ	h_{FE}:	50	MOT
2N1537	3	PNP	Ge	90W	.80	100	75	8.5KcΔ	h_{FE}:	50	MOT
2N1538	3	PNP	Ge	90W	.80	120	90	8.5KcΔ	h_{FE}:	50	MOT
2N1539	3	PNP	Ge	90W	.80	40	30	4KcΔ	h_{FE}:	75	MOT
2N1540	3	PNP	Ge	90W	.80	60	45	4KcΔ	h_{FE}:	75	MOT
2N1541	3	PNP	Ge	90W	.80	80	60	4KcΔ	h_{FE}:	75	MOT
2N1542	3	PNP	Ge	90W	.80	100	75	4KcΔ	h_{FE}:	75	MOT
2N1543	3	PNP	Ge	90W	.80	120	90	4KcΔ	h_{FE}:	75	MOT
2N1544	3	PNP	Ge	90W	.80	40	30	4KcΔ	h_{FE}:	110	MOT
2N1545	3	PNP	Ge	90W	.80	60	45	4KcΔ	h_{FE}:	110	MOT
2N1546	3	PNP	Ge	90W	.80	80	60	4KcΔ	h_{FE}:	110	MOT
2N1547	3	PNP	Ge	90W	.80	100	75	4KcΔ	h_{FE}:	110	MOT
2N1548	3	PNP	Ge	90W	.80	120	90	4KcΔ	h_{FE}:	110	MOT
2N1549	3	PNP	Ge	90W	.80	40	30	10KcΔ	h_{FE}:	20	MOT

NOTATIONS

Under Use

1– Low power a–f equal to or less than 50 mw
2– Medium power a–f >. 50 mw and equal to or less than 500 mw
3– Power > 500 mw
4– r–f/i–f
5– Switching and Computer
6– Low Noise
7– Photo
8– Mixer
9– Local Oscillator
☒– Revised Spec.
10– Chopper
11– Matched Pair

Under Type

A – Alloyed
D – Diffused or Drift
F – Fused
G – Grown
H – Hook Collector
M – Microalloy
Me – Mesa
O – Other
S – Surface Barrier
UNI– Unijunction Transistor
Y – Symmetrical
I – Tetrode

Under Gain Value

Ø – Pulsed

Under fab

* Maximum Frequency
\# Figure of Merit
Δ f_e
Ø Minimum
F_T= Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under Derating

Ø – Infinite heat sink

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE {See Code Below}	TYPE {See Code Below}	MAT	Max. Ratings @ 25° C: P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	Gain: VALUE	MFR. See code at end of chart
2N1550	3	PNP	Ge	90W	.80	68	45	10KcΔ	h_{FE}:	20	MOT
2N1551	3	PNP	Ge	90W	.80	80	60	10KcΔ	h_{FE}:	20	MOT
2N1552	3	PNP	Ge	90W	.80	100	75	10KcΔ	h_{FE}:	20	MOT
2N1553	3	PNP	Ge	90W	.80	40	30	6KcΔ	h_{FE}:	45	MOT
2N1554	3	PNP	Ge	90W	.80	68	40	6KcΔ	h_{FE}:	45	MOT
2N1555	3	PNP	Ge	90W	.80	80	60	6KcΔ	h_{FE}:	45	MOT
2N1556	3	PNP	Ge	90W	.80	100	75	6KcΔ	h_{FE}:	45	MOT
2N1557	3	PNP	Ge	90W	.80	40	30	5KcΔ	h_{FE}:	75	MOT
2N1558	3	PNP	Ge	90W	.80	60	40	5KcΔ	h_{FE}:	75	MOT
2N1559	3	PNP	Ge	90W	.80	80	60	5KcΔ	h_{FE}:	75	MOT
2N1560	3	PNP	Ge	90W	.80	100	75	5KcΔ	h_{FE}:	75	MOT
2N1561	3	Me	Ge	3WØ	25	25	25	500†	h_{fe}:	10db	MOT
2N1562	3	Me	Ge	3WØ	25	25	25	500†	h_{fe}:	10db	MOT
2N1609	3	PNPA	Ge		15	80	60	17KcΔ	h_{FE}:I_C-.50A	10min	DEL
2N1610	3	PNPA	Ge		15	80	60	15KcΔ	h_{FE}:I_C-.50A	25min	DEL
2N1611	3	PNPA	Ge		15	60	40	17KcΔ	h_{FE}:I_C-.50A	10min	DEL
2N1612	3	PNPA	Ge		15	60	40	15KcΔ	h_{FE}:I_C-.50A	25min	DEL
2N1623	2	A	Si	250	540	20	20	.10	h_{fe}:I_C-1.0ma	10	RAY
2SA121	4	PNPG	Ge	15		15	15	100	PG at 10Mc	24db	SONY
2SA122	4	PNPG	Ge	15		15	15	100	PG at 10Mc	30db	SONY
2SA123	4	PNPG	Ge	15		15	15	100	PG at 10Mc	35db	SONY
2SA124	4	PNPG	Ge	15		15	15	120	PG at 10Mc	31db	SONY
2SA125	5	PNPG	Ge	15		15	15	120	PG at 10Mc	28db	SONY
2SB48	2	PNPA	Ge	140	300	16	16	2.5	h_{FE}:I_C- 20ma	43	SONY
2SB49	2	PNPA	Ge	140	300	16	16	3.0	h_{FE}:I_C- 20ma	83	SONY
2SB50	2	PNPA	Ge	140	300	16	16	3.5	h_{FE}:I_C- 20ma	131	SONY
2SB51	2	PNPA	Ge	200	300	30	20	2.0	h_{FE}:I_C- 20ma	43	SONY
2SB52	2	PNPA	Ge	200	300	30	20	3.0	h_{FE}:I_C- 20ma	83	SONY
2SB53	5	PNPA	Ge	200	300	30	30	3.0	h_{FE}:I_C- 20ma	70	SONY
2SB140	5	PNPA	Ge	12W	5.0	40	40	7KcΔ	h_{FE}:I_C-1.0A	74	SONY
2SB141	5	PNPA	Ge	12W	5.0	60	60	7KcΔ	h_{FE}:I_C-1.0A	74	SONY
2SB142	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h_{FE}:I_C-1.0A	24	SONY
2SB143	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h_{FE}:I_C-1.0A	37	SONY
2SB144	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h_{FE}:I_C-1.0A	75	SONY
2SB145	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h_{FE}:I_C-1.0A	37	SONY
2SB146	3	PNPA	Ge	10W	6.0	30	30	7KcΔ	h_{FE}:I_C-1.0A	75	SONY
2SC73	4	NPNG	Ge	30		15	15	20	PG at 2.0Mc	27db	SONY
2SC75	4	NPNG	Ge	30		15	15	10	PG at 2.0Mc	41db	SONY
2SC76	4	NPNG	Ge	30		15	15	10	PG at 2.0Mc	37db	SONY
2SC77	4	NPNG	Ge	30		15	15	10	PG at 2.0Mc	32db	SONY
2SC78	5	NPNG	Ge	30		15	15	20	PG at 2.0Mc	26db	SONY
2SD61	5	NPNA	Ge	100	600	30	25	1.0	h_{FE}:I_C- 10ma	50	SONY

NOTATIONS

Under Use

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3- Power > 500 mw
4- r-f/i-f
5- Switching and Computer
6- Low Noise
7- Photo
8- Mixer
9- Local Oscillator
Ø- Revised Spec.
10- Chopper
11- Matched Pair

Under Gain Value

Ø - Pulsed

Under Type

A - Alloyed
D - Diffused or Drift
F - Fused
G- Grown
H- Hook Collector
M- Microalloy
Me - Mesa
O - Other
S - Surface Barrier
UNI- Unijunction Transistor
Y - Symmetrical
I - Tetrode

Under fab

* Maximum Frequency
\# Figure of Merit
Δ f_e
Ø Minimum
F_T= Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under Derating

Ø - Infinite heat sink

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
2SD62	5	NPNA	Ge	100	600	30	25	1.0	h_{FE}:I_C- 10ma	50	SONY
2SD63	2	NPNA	Ge	100	600	25	20	1.0	h_{FE}:I_C- 10ma	50	SONY
2SD64	1	NPNA	Ge	50	625	25	20	1.0	h_{FE}:I_C- 10ma	100	SONY
2SD65	2	NPNA	Ge	80	625	25	20	1.0	h_{FE}:I_C- 10ma	50	SONY
2SD66	2	NPNA	Ge	80	625	25	20	.80	h_{FE}:I_C- 10ma	25	SONY
B1154	5	A	Ge	400	150Ø	60	55	1.5	h_{FE}:I_C- 10ma	60	BEN
CK4A	5	A	Ge	80	750	30	24	12	h_{FE}:I_B-.40ma	60	RAY
CK13A	4	A	Ge	80	750	30	18	2.5	h_{FE}:I_C-1.0ma	30	RAY
CK14A	4	A	Ge	80	750	30	15	7.0	h_{FE}:I_C-1.0ma	60	RAY
CK16A	4	A	Ge	80	750	30	12	10	h_{FE}:I_C-1.0ma	80	RAY
CK17A	4	A	Ge	80	750	30	10	18	h_{FE}:I_C-1.0ma	140	RAY
CK22A	2	A	Ge	80	750	35	20	1.2	h_{FE}:I_C-1.0ma	90	RAY
CK25A	5	A	Ge	80	750	30	30	4.0	h_{FE}:I_B-1.0ma	30	RAY
CK26A	5	A	Ge	80	750	30	25	6.0	h_{FE}:I_B-1.0ma	40	RAY
CK27A	5	A	Ge	80	750	30	20	11	h_{FE}:I_B-1.0ma	55	RAY
CK28A	5	A	Ge	80	750	30	15	17	h_{FE}:I_B-1.0ma	80	RAY
CK64A	2	A	Ge	80	750	45	29	.80	h_{FE}:I_C-1.0ma	22	RAY
CK65A	2	A	Ge	80	750	45	24	1.0	h_{FE}:I_C-1.0ma	45	RAY
CK66A	2	A	Ge	80	750	35	20	1.2	h_{FE}:I_C-1.0ma	90	RAY
CK67A	2	A	Ge	80	750	35	15	1.5	h_{FE}:I_C-1.0ma	180	RAY
CK798	2	A	Si	250	540	150	80	.10	h_{fe}:I_c-1.0ma	20	RAY
CK799	2	A	Si	250	540	150	125	.10	h_{fe}:I_c-1.0ma	10	RAY
CK800	2	A	Si	200	540	150	125	.10	h_{fe}:I_c-1.0ma	20	RAY
GT31	2,5	PNPA	Ge	125	400	15	15	.80	h_{fe}:	20	AEI
GT32	2,5	PNPA	Ge	125	400	15	15	.90	h_{fe}:	40	AEI
GT33	2,5	PNPA	Ge	125	400	15	15	1.0	h_{fe}:	60	AEI
GT41	4,5	PNPA	Ge	100	500	15	15	4.0	h_{fe}:	30	AEI
GT42	4,5	PNPA	Ge	100	500	15	15	6.0	h_{fe}:	60	AEI
GT43	4,5	PNPA	Ge	100	500	15	15	9.0	h_{fe}:	110	AEI
GT1624	5	NPNA	Ge	120	.50	40	25	1.5	h_{FE}:I_C-1.0ma	70	GTC
GT1658	5	NPNA	Ge	150	.50	25		6.0	h_{FE}:I_C- 20ma	60	GTC
GT1665	5	PNPA	Ge	120	.50	100		10*	h_{FE}:I_C- 10ma	25	GTC
NS100	2	PNPA	Si	400	440	50	15	1.0	h_{fe}:6.0V,1.0ma	40	NAC
NS101	2	PNPA	Si	400	440	50	30	1.0	h_{fe}:6.0V,1.0ma	18	NAC
NS200	5	PNPD	Si	600	290	25	20	200	h_{FE}:5.0V, 10ma	15	NAC
NS300	4	PNPD	Si	600	290	85	45	200	h_{FE}: 10V,1.0ma	25	NAC
ST440	3	NPND	Si	60W	2.08	60	60	8.0	h_{FE}: 12V,1.0A	10	TRA
ST450	3	NPND	Si	60W	2.08	60	60	8.0	h_{FE}: 12V,1.0A	10	TRA
ST3042	10	NPN	Si	50		1.0	1.0	1.0			TRA
ST3043	10,11	NPN	Si	50		1.0	1.0	1.0			TRA
XA151	5Ø	PNPA	Ge	130	300	15	15	3.0Ø†	h_{FE}:I_c- 50ma	20min	AEI
XA152	5Ø	PNPA	Ge	130	300	15	15	5.5Ø†	h_{FE}:I_c- 50ma	40min	AEI

Market News . . .

Sales

Revenue from factory sales of transistors last year rose more than $109 million over the 1958 total and total units sold increased by more than 35 million, according to a year-end compilation by the Electronic Industries Association.

The following chart shows monthly and cumulative figures for unit sales and dollar value in 1959 and 1958:

1959	*Units*	*Dollars*
January	5,195,317	13,243,224
February	5,393,377	14,550,056
March	6,310,286	18,117,560
April	5,906,736	16,864,049
May	6,358,097	19,007,293
June	6,934,213	18,031,593
July	6,030,265	15,618,315
August	7,129,696	18,054,138
September	8,652,526	20,851,290
October	8,710,913	22,109,748
November	7,846,500	22,742,525
December	7,826,194	22,819,931
TOTALS	82,294,120	$222,009,722

1958	*Units*	*Dollars*
January	2,955,247	6,704,383
February	3,106,708	6,806,562
March	2,976,843	6,795,427
April	2,856,234	7,025,547
May	2,999,198	7,250,824
June	3,558,094	8,262,343
July	2,631,894	6,598,762
August	4,226,616	9,975,935
September	5,076,443	10,810,412
October	5,594,856	13,461,857
November	5,440,981	12,441,759
December	5,627,700	16,595,616
TOTALS	47,050,814	$112,729,427

The EIA also reports that this trend is continuing for over 1.7 million more transistors were sold during January than during the previous month and sales revenue was up more than $1.8 million. The number of transistors sold during the first month of this year was nearly double the total for January a year ago while the dollar value of sales shows a gain of $11.4 million.

The following EIA charts give totals for January of this year and December and January of 1959.

	Factory Sales	
	(Units)	*(Dollars)*
January 1960	9,606,630	$24,714,580
December 1959	7,826,194	22,819,931
January 1959	5,195,317	13,243,224

Philco's Lansdale Division has moved its Phoenix, Arizona sales office to San Diego, California.

Knapic Electro-Physics today announced the opening of an eastern sales office in New York City. The new office is located in the Chrysler Building, on Lexington Avenue.

PSI Sales Department has moved to larger quarters in Hawthorne, California.

General Plate Products group of Texas Instruments Inc. has reported that its clad-metal volume in 1959 for the semiconductor industry was more than triple the preceding year's total. Sales in the first two weeks of 1960 equalled the total for the year in 1957.

Transitron Electronic Corporation has established two new sales offices, located in Orlando, Fla. and Dallas, Texas. This brings to 19 the number of national sales offices.

Expansion

Sylvania Electric Products, Inc. has just completed their facility in Towanda, Pa. The plant is expected to be in operation by early summer. It will offer production quantities of both monocrystalline and polycrystalline germanium and silicon.

Rheem Semiconductor Corp. has opened its new $2 million, 100,000 square foot semiconductor plant in Mountain View, Cal.

Pacific Semiconductors, Inc., a producer of microminiature diodes, transistors and other semiconductor devices, has recently moved to larger quarters in Hawthorne, Calif. The new facility, a modern air-conditioned structure with 41,000 square feet of floor space, is larger than the entire original Culver City building in which PSI began operations in June, 1954.

Sperry Semiconductor's multimillion dollar expansion program got under way when ground was broken for their new headquarters, located on a 28-acre site in Norwalk, Conn. Completion of this new plant is scheduled for September, 1960. Future plans call for a 50,000 square foot addition to the 63,000 square foot plant now under construction.

A line of 412 different Germanium transistor types is now available from the newly-formed Electronic Transistors Corp., North Bergen, New Jersey. They are being manufactured under a patent license agreement with the Western Electric Company. The company will manufacture, in addition, a complete line of silicon transistors. All conform to applicable MIL specification. They will also produce power transistors in both semiconductor materials.

Prices

Sylvania Electric Products, Inc., Semiconductor division is now offering its 2N388, an npn Ge alloy junction switching transistor in production quantities. These are priced at $3.68 each in quantities of 1000 or more.

The firm is also offering a switching point contact diode, type D4121 for use in high speed military computors at $4 each in quantities of 1000 to 9,999.

Transitron Electronic Corp. has added type 2N696 and 2N697 diffused mesa transistors to its line. Prices for the 2N696 in 1-99 quantities are $21.75 each and for the 2N697, in the same quantity, $22.70 each; in 100 and up quantities, the units are priced at $14.50 each and $15.15 each, respectively.

Pacific Semiconductor Inc., has available two diffused mesa transistors PT900 and PT901 which dissipate 125w. The PT900 is priced at $155 each and the PT901 at $195 each in small quantities.

Trancoa Chemical Corporation, Reading, Mass., has announced the availability of polycrystalline silicon rods for floating zone crystal growing. The rods are offered in diameter from ⅜″ to 1″. The nominal length of the rods is 10 inches with a boron content of approximately 1.0 ppb. The Trancoa price is $1.00 per gram, a savings of approximately 20 per cent on this form of silicon.

Texas Instruments Incorporated has available for immediate delivery four different units of gallium arsenide tunnel diodes at prices ranging from $9 to $39 in quantity orders.

U. S. Semiconductor Products has announced two new Zener diodes of 10 and 50 watt units with standard tolerances of 5%. Fifty-three different types of 10 watt Zener diodes are available. A typical price is $7.99 for the 1N1351A. In the 50 watt line a typical price is $16.45 for the 1N2962A. The firm has also announced price reductions ranging from 15% to 45%, in approximately 75% of their devices. The major cuts were announced in the line of silicon reference elements in addition to the Zener diode line, a tantalum capacitors and other semiconductor devices.

Fairchild Semiconductor Corp., Mountain View, Cal. has introduced two general purpose silicon transistors which dissipate 1.5w at room temperatures. Type 2N717 is priced at $22.70 and type 2N718 at $24.05. Their new diffused Si transistor, type 2N698, is also priced at $22.70 in quantities from 1 to 99.

Rheem Semiconductor Corp. has available a new line of fast switching, high current silicon mesa transistors. These have been numbered RT5001 through RT5004 and are available in quantity at $38.70 to $49.50 each. In addition the firm has announced prices on their Si glass diodes having a maximum recovery time of 4 mu sec. Types 1N903 through 908, 1N914 and 1N916 have an average price of $4.25 each in quantities of over 100.

National Semiconductor Corp., Danbury, Conn., has reduced prices up to 28% on their silicon alloy transistors lines 2N1440 to 1442 and 2N327A to 329A.

Hughes Aircraft, Semiconductor division has cut transistor prices averaging 25% on *p-n-p* alloy junction types and averaging 20% on *p-n-p* silicon double diffused mesa types. Types 2N1228-1234 and 2N1238-1244 in the alloy junction line will average a reduction of 25%.

General Electric Co., Semiconductor Products department has sample quantities available of 22 ma and 10 ma peak current models of gallium arsenide tunnel diodes priced at $55 and $85 each.

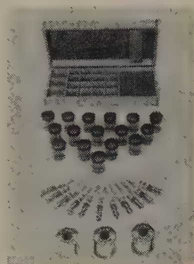
The Lansdale Division of Philco Corporation announced an increased transistor quantity break enabling its industrial distributors to have transistors available in quantities 1 to 999 at factory prices.

Distribution

Schweber Electronics, Mineola, L.I., N.Y. has been appointed a factory-price distributor for Daystrom Pacific Potentiometers and for Westinghouse Silicon Power Rectifiers and Transistors. Up to 1000 pieces of most rectifier and transistor types and up to 2000 pieces per potentiometer type can be obtained at factory prices.

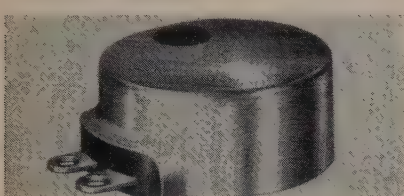
New Products

Solder And Flux Kit



A new solder and flux kit to help design and process engineers do experimental pre-production jobs that cannot be done with standard tin-leader solders is now available from Alpha Metals, Inc. Called the Alpha Solder and Flux R&D Kit, it consists of 16 varieties of soldering chemicals—fluxes, solder paste, flux and dross removers and printed circuit board coatings—11 kinds of flux-filled and solid wire solders in handy dispenser tubes, and 3 different foil solders for making preforms.
Circle 162 on Reader Service Card

Precision Thermostat

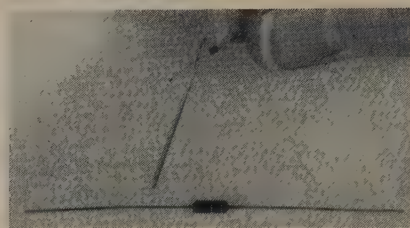


A low-differential precision thermostat that opens or closes on temperature rise has been announced by Spencer Products group of Texas Instruments Incorporated, Metals & Controls division. Designated KLIXON 4286, the device controls temperatures within 5°F maximum limits. For use as a control or warning device in guided missile, aircraft control, computer, crystal oven, etc. Continuous temperature exposure limits are −65°F to +270°F. Handles momentary overrides to +325°F on types designed to open on temperature rise, and overrides to +320°F on types that close on temperature rise. The temperature setting range is 0°F to +250°F.
Circle 154 on Reader Service Card

Tweezers

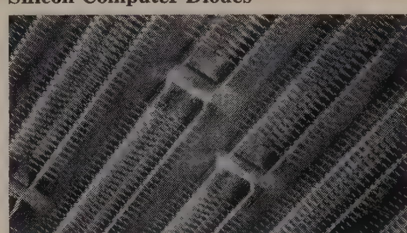
New anti-magnetic "Eremite" Tweezers with high resistance to acids offer the electronic assembly industry important savings in time and tool stores, following development of a new tweezer base metal by Hunter Tools. During extensive tests on the assembly line of a Semiconductor manufacturer, the new Tweezers were used to remove "wafers" from acid baths to a neutralizing liquid. When dipped in a 50-50 solution of hydrofluoric and nitric acids for as long as ten minutes, the Tweezers retained their original appearance and operating characteristics.
Circle 151 on Reader Service Card

Micro-Diode Series



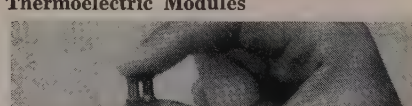
A complete series of micro-diodes has been developed and placed into production by Transitron Electronic Corporation. They include: very fast diffused silicon micro-diodes, a series of high quality micro-regulators; a basic series of high voltage, high conductance micro-diodes; and a micro-stabistor. The basic family of multi-purpose micro-diodes, a series of three high quality diffused-silicon micro-diodes, provides voltage ratings up to 200 volts and the high forward conductance allows a current rating of 50 milliamperes; and can be used in switching applications.
Circle 156 on Reader Service Card

Silicon Computer Diodes



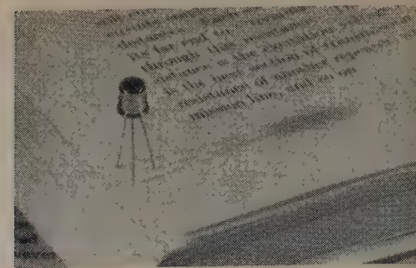
Rheem Semiconductor Corp. ultra fast glass silicon diodes feature maximum recovery time of 4 millimicroseconds together with extremely low capacitance, typically less than 1 micro-micro farad. Listed under type numbers 1N903 through 1N908, plus 1N914 and 1N916, these units give voltage ratings up to 100 volts and average rectified current up to 75 mA. They are hermetically sealed in the standard subminiature glass package and are designed to exceed the requirements of MIL-S-19500B.
Circle 177 on Reader Service Card

Thermoelectric Modules



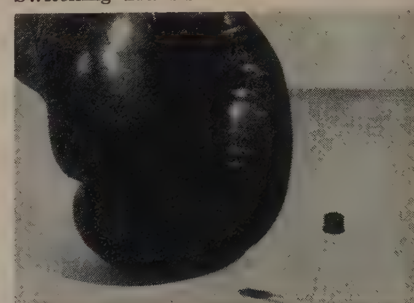
The use of a new bismuth telluride alloy in the production of thermoelectric modules now makes thermoelectricity an efficient as well as economical means of cooling volumes up to 4 cubic feet. Materials Electronic Products Corp. produces the n- and p-type alloy in the form of crystals up to 18 inches in length. Both crystal rods and thermoelectric modules made from the rods are available for experimental use or for production purposes. The p-type alloys have a figure of merit of 4-4.5 x 10^{-3}, and the n-type 2.7-3 x 10^{-3}, which, at 100°C, according to the company, gives Melcor's modules a temperature difference of 105°.
Circle 147 on Reader Service Card

Gallium Arsenide Tunnel Diodes



General Electric has announced the availability of gallium arsenide tunnel diodes in two models. They differ by peak current. The higher current unit has a typical peak current of 22-milliamperes while the other device is rated at 10-milliamperes peak current. Capacitance for both devices is typically 1.5 picofarads per milliampere. The typical peak to valley current ratio is 15 to 1. Typical voltage swing is 1.0-volt.
Circle 163 on Reader Service Card

Switching Transistor



A high-speed switching transistor, 2N-1473 capable of surviving shocks in excess of 20,000 times the acceleration of gravity, has been developed by Sylvania. Designed for use in telemetered torpedoes, projectile fuzes, electronically guided high-impact missiles, and other applications where extreme acceleration shocks are encountered, the new transistor has maximum ratings of 40 volts Vcbo, 20 volts Vceo, 15 volts Vebo, 400 ma. Ic, −50°C to +75°C storage temperature, +75°C junction temperature.
Circle 161 on Reader Service Card

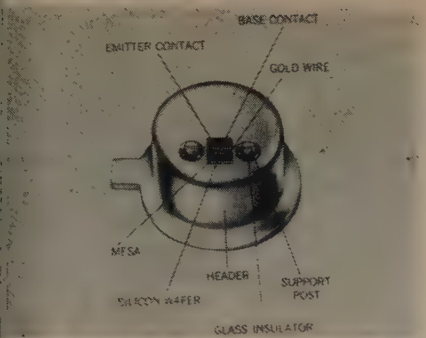
Zone Refiner

Lindberg Engineering Company offers a Multiple Tube Horizontal Zone Refiner for germanium. From one to 12 quartz tubes can be mounted and used simultaneously, traversing a molten zone in each tube. A direct current drive powers a threaded shaft which is continuously variable from .8 to 16 inches an hour. Return speed is continuously variable from 40 to 800 inches an hour. Each tube will accommodate a 30″ long carbon boat. Minimum vibration of the fixture allows single crystal growing in the horizontal position.
Circle 180 on Reader Service Card

Planar Transistor

Fairchild Semiconductor Corporation introduces its new diffused planar structure silicon transistor, 2N1613. The new unit is different from mesa types in that both the collector to base and base to emitter junctions are embedded in the top surface of the planar structure. It has typically .0005 microamp ICBO at 60 volts, guaranteed useful beta over a range of collector currents from 100 microamps to one half ampere, a VCBO of 75 volts. Will dissipate 3 watts in JEDEC TO-5 package at 25°C case temperature.
Circle 172 on Reader Service Card

Mesa Transistors



According to National Semiconductor Corporation, a new class of diffused silicon "mesa" transistors has been developed by them specifically to meet military and industrial requirements for production quantities of high quality, tightly controlled devices. Initially the new techniques are being used to produce two types of *n-p-n* transistors, the NS200, for switching applications in computer circuitry, and the 2N752 for high frequency amplification in video amplifiers, I.F. strips, telemetering and other applications. Output capacitance of both is 5 mmfd, leakage current at 150°C is 3 microamps for the NS200 and 5 microamps for the 2N752. Guaranteed minimum gain-bandwidth product for both is 200 megacycles. Collector saturation resistance of the NS200 is 35 ohms, 40 ohms for 2N752. Beta fall-off from 1 to 100 milliamps is less than 35% of peak value.

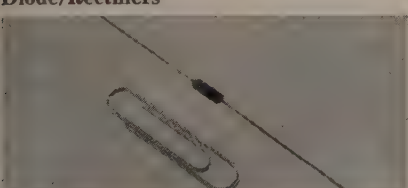
Circle 152 on Reader Service Card

Hex Mount Zener Diodes

10-watt Zener diodes in standard 7/16" hex stud (DO-4) package are now offered with 5% standard tolerance by U. S. Semiconductor Products. Reverse breakdown voltages (E_z) range from 7.5 volts to 100 volts, according to part number. The following series are available: 1N1351A-1N-1375A; 1N1806A-1N1808A; 1N1816A-1N-1836A; 1N2008A; 1N2498A-1N2500A. They provide excellent voltage regulation or reference, clipping, surge and under or over-voltage protection, meter protection, and may be used in many other unusual applications.

Circle 170 on Reader Service Card

Diode/Rectifiers



Designed to operate at temperatures up to 200°C., new subminiature silicon diode/rectifiers in hermetically-sealed glass case (MP 100 through MP 600), have been developed by General Instrument Corporation and are now available in production quantities. Of fused junction construction, with pigtail leads, they are built to meet military specifications, cover the range from 100 to 600 volts peak inverse, and operate at ambient temperatures from −65°C. to +200°C. At 200°C. and 225 peak inverse voltage, maximum average rectified current is 50 mA.

Circle 168 on Reader Service Card

THE TREND IS TO UNITRON

Wire Bonder

Kulicke and Soffa Mfg. Co. Model 400 Transistor Wire Bonder is used to bond the contact wires between the semiconductor material and the header terminal post in transistor manufacturing. The basic instrument can also be adapted to other micro-assembly techniques. The instrument features an optional continuous wire feed. (The standard model has a Wollaston wire feed.) Other features include a single-control, chessman-type micropositioning mechanism for X-Y axes adjustments.

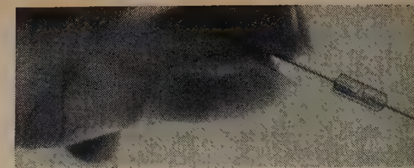
Circle 169 on Reader Service Card

Gas/Air Recirculator

C. I. Hayes, Inc. recirculating Molecu-Dryer Type MS-R is a simple, compactly designed gas and air dryer complete with an atmosphere recirculating unit. This new adsorptive unit has been designed specifically around Linde Company's 5A Molecular Sieve material. Type MS-R incorporated into a closed-cycle system, now permits substitution of pure dry air, with dew points to −100°F or lower, for tank nitrogen ordinarily used for "dry box" assembly of transistors, diodes and other electronic parts.

Circle 159 on Reader Service Card

Tunnel Diodes



Sperry Semiconductor has announced the immediate availability of germanium tunnel diodes covering a wide range of typical peak currents. Sample quantities of types T101-T105, with peak currents ranging from 0.8 ma to 20.0 ma are available. Peak to valley current ratios on all types are in excess of 5.0 to 1, typically 8.0 to 1. They have a typical peak point voltage of 50 millivolts and typical valley point voltage of 250 millivolts. Operating and storage temperature range is from −55 to +100°C. The units have a 100 milliwatt dissipation rating at 25°C.

Circle 175 on Reader Service Card

Micro-Transistor Series

Specifications on a new series of Micro-Transistors were released by Pacific Semiconductors, Inc. One series is approximately 1/50th the size of the standard TO-5 package, An alternate type, available for experimental use is in ultra-micro-miniature form, and is 1/200th the size of the TO-5 package. The new Micro-Transistor is a triple-diffused *n-p-n* silicon mesa device designed as a low-power high speed switch.

Circle 164 on Reader Service Card

New Power Supply

Victory Electronics, Inc. announces the "Victory Variant", a power supply on which you can change regulation without any change of wiring or removing supply from its mounted position. The regulator can be easily removed and operated separately and the power unit can be operated as a 1% regulated power supply. When they are reunited, they form a highly regulated power supply.

Circle 166 on Reader Service Card

Ultrasonic Cleaner

A new addition to the McKenna Laboratories "Poly-Sonic" series ultrasonic cleaners, which feature several simultaneous ultrasonic frequencies, the V-100 provides especially thorough cleaning because it produces uniform concentration of ultrasonic power throughout the cleaning chamber. Completely uniform cleaning results are obtained throughout the volume of the container even in a parts basket. Another feature of the "Poly-Sonic" units is the more effective cleaning through the use of heated solutions.

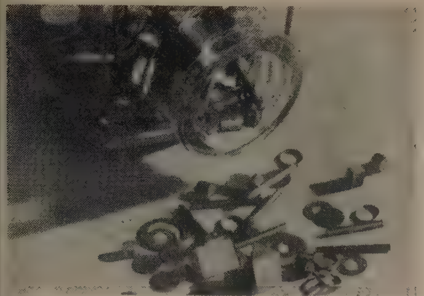
Circle 196 on Reader Service Card

Silicon Junction Rectifier

Trans-Sil Corp. Type MR series of double-diffused junction silicon rectifiers will deliver up to 3.0 amperes, half wave, with proper heat sink, in ambients up to 150°C. In full wave circuits, currents up to 9.0 amperes can be realized. They are hermetically sealed cells particularly suited for power supply and magnetic amplifier applications.

Circle 179 on Reader Service Card

Soft Solder Alloy Preforms



Using ultra-pure vacuum casting techniques, Accurate Specialties Co., Inc., is now offering industry a complete range of soft solder preforms with alloying elements of lead and tin held to 99.999 + % purity. Melting points range from 361°F to 689°F. Preforms are available in the form of flat washers, discs and pellets. In order to assure continued purity, the parts are packaged in argon or other protective atmospheres prior to shipment thus assuring indefinite shelf life.

Circle 158 on Reader Service Card

Solid State Current Limiter

Microlectron Current Limiters are made entirely of electrically conductive ceramic raw materials, which are deposited as thin film constructions on glass or aluminum oxide substrates. The device is a junction which is highly sensitive to overload currents. Consequently it can be used to protect other components which may be seriously affected by overload. It can be used to protect transistors, rectifiers, diodes, galvanometer movements and the like. It is particularly useful in protecting semiconductor junctions, since its response time is faster than the time-current required to damage a typical junction.

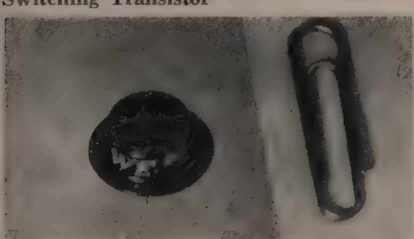
Circle 149 on Reader Service Card

Gas Diffusion Furnaces

A major breakthrough for gas diffusion in the semiconductor industry, the new DZ series Furnaces are announced by BTU Engineering Corporation for continuous alloying, fuzing, bonding, brazing, soldering and metal-to-glass sealing under controlled atmospheres. Features include: a true temperature flat to specified tolerances, stepless temperature control with controlled rectifiers, a tiltable furnace for best results in open end or closed tube diffusion, optimum insulation for stability, provisions to increase the number of controls for specific results.

Circle 157 on Reader Service Card

Switching Transistor



A new high speed, high current silicon switching transistor, designated 2N1072, is now available for military application from the Radio Division of the Western Electric Company. The unit is a double diffused *n-p-n* mesa type transistor, capable of switching currents up to 1 ampere with rise and fall times of 50 millimicroseconds. At 750 milliamperes of collector current, this transistor has a saturation voltage between 0.7 minmum and 2.0 maximum, its hFE is 15 minimum, and the base input voltage is 0.7 volt minimum and 1.8 volts maximum.

Circle 173 on Reader Service Card

Solder Paste Alloys

The solder paste alloys developed by Physical Research Laboratories are highly specialized solder media which utilize special atomized eutectic alloys and precision controlled flux chemicals especially suited for soldering nickel chrome resistance alloys, stainless steel, and numerous other complex alloys known to those in the electrical and electronics fields. PRN 390 has a melting point of 225 degrees C. and contains a special proprietary flux that is capable of sufficient activity, yet leaves no corrosive residue. LS-59 has a melting point of 585 degrees F. and provides greater bond strengths. PRN-400 is a solder paste alloy with a melting point of 439 degrees F.

Circle 160 on Reader Service Card

Photoconductive Cells

One-half inch diameter power cells of the photoconductive type, combining relatively high dissipation ratings with a small, hermetically sealed package, have been announced as available in a new series, the 500 Line, by Clairex Corporation. Type 504 is an extremely sensitive Cadmium Selenide type with a relatively high speed of response; the 505, Cadmium Sulphide.

Circle 187 on Reader Service Card

Transistor Tester

A transistor test and classification computer is being manufactured by Industro Transistor Corporation. The instrument, ITVAC (Industro Transistor Value Automatic Computer), is available in several models, and can test 750 transistors per hour, classify them according to programmed specifications and record the test data of each unit in one or more of several recording methods. Accuracy of the machine is on the order of ¼ of 1%, and is maintained by a series of self-checks that ITVAC undergoes before every transistor test. A battery of standard cells built into the machine is used as a reference by the machine before testing.

Circle 165 on Reader Service Card

Silicon Transistor Series

Western Transistor Corporation revealed development and production of a new series of *p-n-p* silicon alloy transistors, carrying the trade name "WesTran". The '327' series is designed for switching and general purpose application at low and medium power levels. Engineered to exceed Mil Spec T-19500, they are more structurally rigid than required in such environmental conditions as acceleration, shock, strong impact, and thermal fatigue.

Circle 192 on Reader Service Card

Component Life-Test Oven

A new elevated-temperature thermostatically controlled life-test oven with complete internal power-supply and test-facility circuitry has been introduced by ITT. The new unit handles 660 bi-polar components or 330 tri-polar devices. Standard units are rated at 125°C maximum. Test circuitry is rated at 750 volts and 5 amperes with resistance less than 0.5 ohm. Power requirements are 1600 watts at 115 or 230 volts and 50 or 60 cycles.

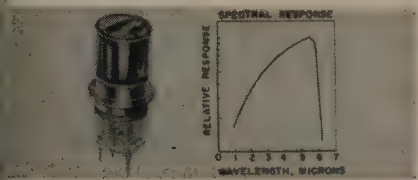
Circle 193 on Reader Service Card

olid Circuit Networks

: Texas Instruments Incorporated has announced the availability of its Solid Circuit semiconductor networks. Each network is a complete functioning electronic circuit fabricated within a single piece of high-purity semiconductor crystal the size of a matchhead. The new networks offer promise of greatly improved reliability in addition to dramatic size reduction. Wide application is anticipated in missile and airborne electronics where miniaturization and reliability are of prime importance. Applications already are being made in the computer field.

Circle 155 on Reader Service Card

nfrared Detector



A new infrared detector of extremely small area (0.1x0.1mm²) is now being produced by Radiation Electronics Company. Utilizing the photovoltaic effect in indium antimonide at liquid nitrogen, the Model J-02 detector exhibits typical NEP values of 2×10^{-12} watt at 5 microns and 4×10^{-12} watt for 500°K Blackbody. It responds from the visible region to 5.7 microns with a time constant of less than one microsecond.

Circle 186 on Reader Service Card

Insulator Wafers

Hard-anodized insulator wafers for stud mounted diodes have been added to Monadnock Mills line of insulator wafers for semiconductors. Wafers provide outstanding dielectric insulation and thermal conductivity. Installed between diode and chassis and between hex jam nut and chassis. Extruded center hole insulates stud from chassis and eliminates necessity for separate insulating bushing.

Circle 194 on Reader Service Card

Diode Testing System

For manufacturers and users of diodes, the Flite-Tronics TM-1 Visual Diode Evaluation Monitor combined with the Model DE-48 Module simulates aging and provides rapid, efficient dynamic testing of diodes in quantity. Forward conduction current and reverse voltage of the diodes under test are readily monitored, when the output of the TM-1 is connected to a dual trace oscilliscope.

Circle 195 on Reader Service Card

Transistor Test Set

The Dynatran Model 1802 RF Transistor Test Set is designed to measure the important RF parameters of both *n-p-n* and *p-n-p* transistors. This set provides direct readings of the alpha cut-off frequency and gain bandwidth product for junction transistors up to 50 megacycles. It also provides direct readings of the r'_bC_c product and the collector ouput capacity. This instrument is complete in itself and requires no auxiliary equipment. It is power line operated and contains no batteries.

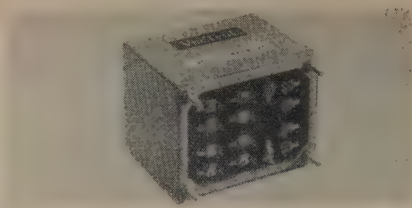
Circle 150 on Reader Service Card

Silicon Power Transistors

A new group of 12 diffused-junction power transistors of the silicon *n-p-n* type was announced by RCA. They are intended for a wide variety of applications in industrial and military equipment operating at temperatures ranging from −65°C to +175°.

Circle 189 on Reader Service Card

Silicon Power Rectifiers



A full range phase shift control for Silicon Controlled Rectifiers of all makes and ratings has been announced by Vec-Trol Engineering, Inc., under the registered trademark "SILICONTROL." A supersensitive phase shifting network applies 60 cycle steep pulses of constant amplitude to rectifier gates and varies their phase angle over 180° to control the rectifier output from zero to maxi um. Pulse rise time is only a few microseconds.

Circle 185 on Reader Service Card

Semi-Automatic Tester

Monitor Systems, Inc. announces the development of a component checkout system, the SATT (Semi-Automatic Transistor Tester). The rate of transistor testing is in the order of 30 or 60 tests/second, within an accuracy of 0.5%. Though primarily intended for the transistor industry, is easily modified to test many other types of electronic components (resistors, capacitors, diodes, tubes, etc.) printed cards, and subassemblies.

Circle 182 on Reader Service Card

Tunnel Diode Curve Tracer

The new Trak Electronics Tunnel Diode Curve Tracer is an instrument for use with a laboratory oscilloscope and presents the current-voltage characteristic of tunnel diodes throughout the negative resistance region. The available range exceeds that necessary for testing currently available tunnel diodes in anticipation of new diodes with different characteristics. The accuracy of conversion from current to voltage is $\pm 1\%$.

Circle 183 on Reader Service Card

Ultrasonic Cleaner

A new Circosonic cleaner that combines the advantages of high frequency ultrasonic cleaning, plus mechanical agitation action in a single unit, has been developed by the Circo Ultrasonic Corporation. In the new unit, the ultrasonic sound waves loosen the foreign matter from crevices, blind holes and threads, leaving the agitation action to float it away. Generator (PG500) and transducers (two model 4090B's) have an output of 500 watts av., 1,000 watts peak; frequency of 40 KC; power output of 1,500 watts, 115 volts, 60 cycles, 1 ph., weight of 75 pounds. Overall dimensions of the units are 19″ wide x 14″ high x 15″ deep.

Circle 191 on Reader Service Card

Dry Box Gloves

"Rad-Bar" lead-loaded dry box gloves, made by an exclusive formulation of Charleston Rubber Company now are being offered in standard heavyweight and lightweight thicknesses, in several dimensions, styles and hand sizes. These lead-loaded Neoprene gloves are of a density of 3.95 grams per cubic centimeter. Tests conducted on Cadmium 109 at .087 Mev. show that the heavyweight glove, with 0.060″ nominal overall glove thickness has a lead equivalent of 0.36 MM and the lightweight glove with 0.030″ nominal overall glove thickness has a lead equivalent of 0.10 MM.

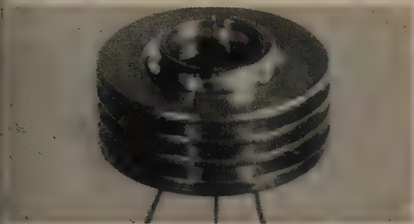
Circle 153 on Reader Service Card

[H]all-Effect Device

The latest in a series of new Halltron [H]all-effect devices has been introduced [b]y Ohio Semiconductors, Inc. An axial [fi]eld probe known as the Model HP-315, [it] utilizes indium arsenide (InAs) for the [a]ctive element. It is capable of applica[ti]on from —35°C to +85°C and has a [te]mperature coefficient of approximately [-]0.1% per degree C. With a control cur[re]nt of 100 milliamperes and a flux density [o]f 10 kilogauss, the nominal open circuit [H]all output voltage is 100 millivolts.

Circle 181 on Reader Service Card

[H]eat Sinks



The availability of two new heat sinks [f]or JEDEC-30 transistors was announced [b]y the Thermolloy Company. The #2208 [a]nd #2209 are general purpose heat sinks [f]or TO-5 and TO-9 outline transistors. De[s]igned especially for Mesa transistors, [t]hese heat sinks can be used both for [p]rinted circuit board applications and [m]ounting directly to metal chassis.

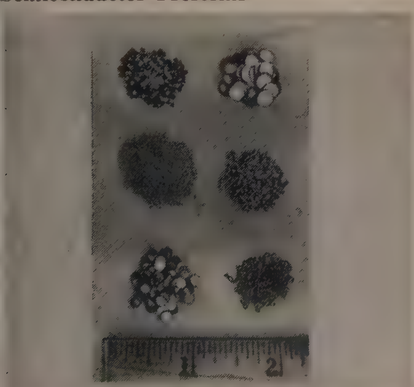
Circle 190 on Reader Service Card

Alumina Abrasives

Geoscience Instruments Corp. announces abrasive crystals which meet the critical requirements of the electronic and semiconductor industry and which will produce the ultra high polished surfaces necessary for advanced device fabrication. "Corunda" (Liquid Sapphire & Liquid Ruby) is produced under the most exacting conditions assuring a new standard of uniform particle size. Homogeneity is certified by the laboratory analysis of each batch produced. Every run is graded and the particle and size and lot number recorded on the containers.

Circle 167 on Reader Service Card

Semiconductor Preforms



Lead-antimony preforms for *n-p-n* type transistors are now available from Alpha Metals, Inc. The alloy combination most commonly used consists of 90% lead, 10% antimony, and has a melting point of 252° C. Other alloy combinations, too, are available. The purity of the metals used exceeds 99.999%. They are available as spheres, discs, cylinders, cubes, and are also preformed into drops, washers, rings and special shapes. Alpha fabricates this alloy as cylinders with a diameter of .008" and a thickness of .010" in production quantities.

Circle 145 on Reader Service Card

Industry News

CONFERENCE CALENDAR

The Following June 1960 Meetings Are Scheduled:

June 12-15 American Nuclear Society meeting, Chicago.

June 15-18 American Physical Society, McGill University, Montreal, Canada. Sponsored by AIP.

June 20-24 AIEE Summer General Meeting, Chalfonte-Haddon Hall Hotel, Atlantic City, N. J.

June 22-24 Electronic Standards & Measurements Conference, National Bureau of Standards Boulder Labs, Boulder, Colorado. Sponsored by PGI, NBS, AIEE. For Information: George E. Schafer, National Bureau of Standards, Boulder, Colo.

June 23-24 Workshop on Solid-State Electronics, Purdue University, West Lafayette, Indiana. Sponsored by PGE, ASEE. For Information: Dr. James Mulligan, New York University, University Heights, Bronx, N. Y.

June 26-July 1 American Society for Testing Materials Annual Meeting, Chalfonte-Haddon Hall Hotel, Atlantic City, N. J.

June 27-29 National Convention on Military Electronics, Sheraton Park Hotel, Washington, D. C. Sponsored by PGMIL. For Information: Dr. Craig Crenshaw, Dept. of Army, SIGRD-2, Washington 25, D. C.

Dr. Farrington Daniels, vice president of the National Academy of Sciences and professor emeritus of the University of Wisconsin, will present the annual Edgar Marburg Lecture at the 63rd Annual Meeting of the American Society for Testing Materials, in Atlantic City, June 29. This annual lecture is a memorial to the first secretary of ASTM and was established to emphasize the importance of furthering the knowledge of properties and testing of engineering materials. The launching of the artificial planet, Pioneer V, to orbit around the sun focuses attention dramatically on the use of solar energy to power the radio transmitters which are sending scientific data back to earth. Dr. Daniels will discuss the abundance and limitations of solar energy and will review solar energy research, emphasizing particularly the new materials which are necessary in the successful application of solar energy. The research review will include the subjects of heating, cooling, distillation of salt water, solar engines, photoelectricity, thermal electricity and photochemistry. New materials to be discussed will include: plastics for reflectors and covers for solar collectors; silicon in solar cells; solid state devices for thermoelectric and thermionic energy converters; refrigerant systems for possible appli-

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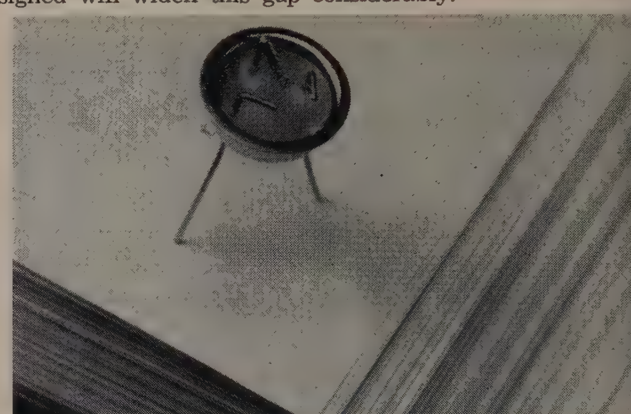
cation in solar cooling cycles; and selective coatings for attaining high efficiency energy absorbers.

RESEARCH & DEVELOPMENT

A new concept in transistor design involving high speed switching at low power levels for computer usage has been achieved by the Lansdale Division of Philco. Called a "micro-energy" switch, this device has been designed and constructed so that all internal device capacities are exceedingly small. Philco's first micro-energy switch features an emitter transition capacity less than one-third and a collector capacity approximately one-half that of conventional units. The gain bandwidth product is specified to be greater than 125 mc at a collector voltage of 1 V and a collector current of 1 ma and the beta characteristic optimizes at approximately 1 ma. The minimum saturation current gain of the transistor is 25 at a collector current of 2 ma. This switch will operate in simple high-speed logic circuits at pulse rates in excess of 10 mc when switching collector currents as small as 1 ma from collector supply voltages as small as 1 V. It permits the design of high-speed logic circuits operating with an overall power consumption of less than one-third that of circuits designed with conventional transistors. Micro-energy switches now being designed will widen this gap considerably.



The development and commercial availability of a man-made diamond for metal bonded grinding wheels has been announced by the Metallurgical Products Department of General Electric Company. Typical particles of the new diamond are of single crystal and blocky shape, with many showing regular crystal faces. The color ranges from light green to gray-black with light colored particles predominating. Crystal surfaces are smoother than the resinoid-vitrified bonded type, but are still considerably more irregular than the surface of natural diamond fragments of similar size, according to the company. They are available in sizes up to 100 mesh, and will be used in metal bonded grinding wheels for lens laps, glass grinding, (including pencil edging and beveling) electrolytic grinding and conventional grinding on cemented carbide. Other applications favored are forming and shaping of synthetic sapphires, cutting germanium and quartz, and the grinding of ceramics for missile components, such as ceramic nose cones.

Under the sponsorship of a Signal Corps research and development contract and also a separate fabrication contract, an X-band solid-state maser amplifier, the "ruby maser," was developed and fabricated by Hughes Aircraft Company. The effort under the contract was directed toward obtaining the maximum gain-bandwidth product and toward making the amplifier as stable and compact as possible. Achievement of substantial miniaturization in

(Continued on page 76)

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(*from page 74*)

maser design is reflected in the over-all weight and size which are 25 pounds and ⅓ cubic foot respectively. The gain-bandwidth product of this amplifier is 105 Mc when operating at the temperature of liquid helium (4.2° K). The paramagnetic crystal employed in the amplifier is synthetic ruby having about 0.1% chromium concentration. Basically, high performance, reliability and miniaturization all are achieved by the use of a "ruby cavity."

An analysis of the efficiency of solar batteries such as those mounted on the paddles that power the paddle wheel satellite was presented at the American Physical Society meeting in Detroit recently by Drs. Hans J. Queisser and William Shockley. In commenting on his investigation carried out under contract with the Air Force Wright Air Development Center, Dr. Shockley said "The investigation leads to the important conclusion that no known basic reason precludes an improvement of 50% in solar batteries by better fabrication methods. The relative inefficiency of present solar batteries arises from unknown and uncontrolled recombination centers which absorb unnecessarily large fractions of the electric current generated by sunlight. Research on the nature and elimination of these unwanted centers will pay big dividends in the program of sun-powered batteries."

General Electric Company announced that it has developed a transistorized multiplex-carrier system capable of handling up to 600 voice frequency channels on a single radio beam. Fully transistorized, the new single sideband suppressed carrier system has toll quality capable of meeting international and domestic long-distance standards, according to the company. It will be of primary importance to telephone and wire line companies but also will have substantial benefits for utilities, railroads, pipelines and other users of microwave and cable systems.

Bendix Radio Division's 2R series transistorized railroad radio provides end-to-end, train-to-train, and wayside-to-train communications. Its advantages include greater receiver sensitivity, 12-watt audio output, and facilities for up to four-channel operation, according to the company. Other features include completely transistorized power supplies for the 12- and 72-volt units, transistorized receiver, transistorized audio circuit in the transmitter, a transistorized "protective" circuit in the 72-volt unit to guard against overloads, an optional "battery saver" circuit for the 12-volt unit to reduce drain when the unit is in stand-by (receiving only) condition.

Minnesota Mining & Manufacturing Co. officials stated recently that a thermoelectric generator research and development contract just awarded 3M by the Navy Department represents an important step in the development of practical applications for thermoelectric materials and devices. The 3M Company was one of two firms awarded research and development contracts for a 500 watt gasoline or gas fueled thermoelectric field generator. The portable generator, which is designed to power surveillance radar, communications equipment and other field gear, must weigh no more than 35 pounds.

Robert W. Fritts, manager of 3M's thermoelectricity program, said, "We feel the major markets, both military and commercial, for thermoelectric generators in the years immediately ahead will involve gas and gasoline burning devices producing 1000 watts of power or less. We have been working for some time on the design and construction of a device very similar to that which the Navy has specified and our thermoelectric group has many years of experience in working with modified lead telluride, which is considered one of the best materials available for generator applications such as this."

New Literature

The Lansdale Division of Philco Corp. has made a Transistor Application Guide available in response to industry's many queries concerning the proper selection of transistor types for specific applications. The guide, in booklet form, indicates suitable transistor types for each major application. Transistors are classified in terms of one or two important parameters. Information is primarily presented in graphs and curves for simplicity. Data given by charts is intended to be reasonably typical of performance that has been obtained in practical circuits.

Circle 100 on Reader Service Card

A new group of technical data sheets describing the physical properties of alloys used in the manufacture of semiconductor devices has been released by Alpha Metals, Inc. These latest "Semiconductor Data Sheets" describe the properties of aluminum-silicon, lead-silver and indium-gallium alloys. Part of a continuing series, each data sheet contains a phase diagram of one of these alloys, a description of its phase relationship and crystal structure, properties and fabrication possibilities.

Circle 101 on Reader Service Card

A two-color, four-page brochure has been prepared by Schweber Electronics to aid buyers and engineers in the selection of Vitramon Capacitors. It contains illustrations and details of Axial and Axial-Radial Series and the new ceramic Micro-Miniature capacitors, and lists their availability by part number, capacity, dimensions, etc.

Circle 102 on Reader Service Card

An up-to-the-minute summary of the forms, properties and applications of Dow Corning Silicones is contained in a 16-page brochure. Products reviewed range from adhesives to release agents, laminating resins to rubber compounds, and electrical insulation to water repellents. The table of contents is arranged according to applications enabling quick, easy reference to silicone materials.

Circle 103 on Reader Service Card

For information concerning Transistors, Diodes & Rectifiers, D.A.T.A. offers complete, worldwide, up-to-date Reference Service. Characteristics tabulations in each category reduce the "dogwork" and give immediate information four ways: Listed first in major characteristics sequence, you can quickly locate the type best suited to your requirements, similar types are grouped together. All manufacturers of each type are included in the Type Number Cross-Index. Each manufacturer's complete product line is itemized separately. Complete, superseding editions of each of their three tabulations are issued semiannually, plus a supplement to the Transistor Characteristics Tabulation between each complete edition. Price and information on free offer with each new subscription available from D.A.T.A., Inc.

Circle 104 on Reader Service Card

Wakefield Engineering, Inc., announces the availability of their technical Bulletin No. 260 and Price List on Semiconductor Heat Exchangers, Series 5000, for Medium Pressure Forced Air Cooling Systems using transistors, Zener diodes and rectifiers. Contains a complete description on the material, construction, finish, mounting, and ducting and baffling of the heat sinks. Illustrations, line drawings, and Characteristic Curves are given for each of the five models.

Circle 105 on Reader Service Card

Dialight Digest consists of 24 pages (8½" x 11") of condensed technical data on a wide range of Dialco Pilot Light Assemblies and the lamps for which they were designed. A section is devoted to Lens Holders with lenses for panel mounting, Cable Connectors, and Bracket-Mounted Sockets for small lamps.

Circle 106 on Reader Service Card

The new Kepco catalog (B601) of Voltage Regulated Power Supplies gives full descriptive data of active standard models in the transistorized, vacuum tube, magnetic and hybrid design groups of the company's wide line of power supplies. A new dual index by design group and output voltage range provides easy access to this data.

Circle 107 on Reader Service Card

Performance characteristics, description and tables showing diameters of wire available are shown in CERON ST data sheet, from Kanthal Corp., on resistance alloy wire with new dual layer, high temperature insulation of ceramic and Teflon (TFE fluoro-carbon). Complete specification data is given.

Circle 108 on Reader Service Card

Allied Radio Corporation announces publication of a greatly expanded sixth edition of the Allied Semiconductor Directory. This complete purchasing directory includes the newest power, high-speed switching, high-current, Zener diodes and diffused junction mesa type transistors. Also listed are the latest micro-diodes, voltages-variable capacitors and photo-sensitive devices.

Circle 110 on Reader Service Card

Anchor Metal Co., Inc. announces the publication of a booklet written especially for production personnel involved in soft and hard soldering. The 6-page manual "Anchor Solder and Its Proper Application," provides an interesting summary of the origin and uses of the soldering process throughout the world. In addition, there is a section devoted to the soldering of aluminum including tips on the most effective method.

Circle 111 on Reader Service Card

Sprague Electric Company has made available Engineering Data Sheet No. 6201B on their Resin-Dipped Formulation 23 Monolythic Ceramic Capacitors. Sheet lists performance characteristics and gives a Cross Reference Guide.

Circle 112 on Reader Service Card

Abbeon Supply Company has issued Information Bulletin 569 containing facts about Dehumidification for industrial plants, warehouses, stockrooms and laboratories. Answers typical questions in this field and illustrates available equipment with prices for various units.

Circle 113 on Reader Service Card

Personnel Notes

William J. Peltz, vice president and general manager of the Lansdale Division of Philco Corporation, has announced new staff and managerial appointments as part of the expansion planning of this division. Stephen L. Levy, assistant to the vice president and general manager of the division; H. Kenneth Ishler, general manager of semiconductor operations; Raymond M. Cotter, director of manufacturing for semiconductor operations; George W. Pratt, director of engineering service; Charles Lupton, director of industrial relations; Cyrus H. Warshaw, director of marketing and William F. Maher, manager of sales.

As part of an expansion and reorganization of General Instrument Corporation's Semiconductor Division, a series of promotions and engineering staff additions have been announced by Maurice Friedman, Vice President and General Manager of the Division. They include: William J. Feldman, Chief Industrial Engineer, Eric J. W. Evans, Chief Germanium Diode Process Engineer; E. Thomas Middleswarth, Chief Glass Technologist; Ralph H. Garten, Senior Industrial Engineer; Lawrence P. Goetz, Senior Process Engineer; Kurt J. Sonneborn, Senior Process Engineer.

The J. T. Baker Chemical Company, Phillipsburg, New Jersey, through its President, Dr. J. R. Stevens, announces the appointment of Dr. Charles H. Schramm as Scientific Director.

Harold C. Potter has been appointed manager of sales for General Electric's Semicondutcor Products Department. Mr. Potter's office is located at the Department's marketing headquarters in the Charles Building, Liverpool, N.Y.

Ira W. Hutchison, Manager of the International Department, Dow Corning Corp., Midland, Michigan, has also been named president of its new subsidiary, Dow Corning International S.A.

Boonton Electronics Corporation of Morris Plains, New Jersey has announced the appointment of Raymond E. Lafferty as Chief Engineer. Mr. Lafferty will be concerned with the design and development of new test equipment and with application engineering.

Dwight N. Wait has been named general manager of Kemet Company, Division of Union Carbide Corporation it was announced by John D. McQuade, Pres.

Frank G. Gustafson has been appointed supervisor of the process engineering department in Plant 7 at Norton Company, Worcester, Mass. Joining the company in the sales training course in 1952, he has worked, successively, as a grinding engineer, sales engineer, supervisor of the sales engineering department and chief sales engineer of the abrasive division.

Charles H. Sommer was elected president of Monsanto Chemical Company recently and Charles Allen Thomas was elected chairman of the Board of Directors.

The appointment of Ernest V. Smith Field Representative for Schweber ectronics, components distributing firm Mineola, L.I., N.Y., has been announced A. William Suarez, the company's New gland District Manager. Mr. Smith will rvice components users in the New gland area and in and around Schenctady, N.Y. The appointment coincides th the establishment of a regional pot for G. E. Tantalytic (R) Capacitors, tramon Capacitors and Daystrom Po-ntiometers, located at 1191 Washington venue, West Newton, Massachusetts.

Affiliation of two new executives with acific Semiconductors, Inc., and their pointment to key manufacturing positions, was announced recently by Dr. Harr Q. North, president. Robert M. Wood, ins PSI as Manager of the Transistor ant. David M. Edwards, has been selected as Manager of Manufacturing Planning and Control. They will report to arry Lindgren, Manager of Manufacring.

John Bettencourt has been appointed anager of micro-alloy diffused transisrs in an announcement by Edward J. uirk, semiconductor plant manager for BS Electronics.

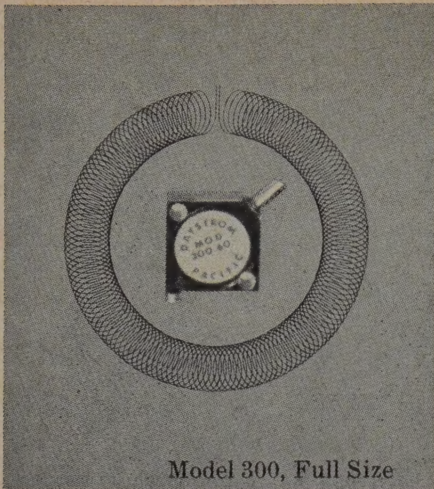
Arthur W. Keough has been appointed uality Control Manager of the Los Anles division of the Avnet Electronics orp., it was announced recently by obert H. Avnet, Chairman of the Board.

Norman J. Golden has been promoted vice president-research and developent of the Semiconductor Division of offman Electronics Corporation. He suceeds Dr. Morton B. Prince, who recently as named vice president and general anager of the division.

Fairchild Semiconductor Corporation as appointed Robert Shultz to head its pplications engineering section, Dr. Vicr Grinich, Director of Engineering, anounced recently. He has been in the lid state electronics field since 1951.

Herbert O. Boellhoff has been named lethods and Procedure Supervisor by perry Semiconductor. Mr. Boellhoff omes to Sperry with wide experience in e semiconductor and transistor fields.

William W. Taylor has joined the Biddle ompany as an account executive to help t up an Electronics Section. He was rmerly Ad Manager, General Sales lanager and Staff Assistant to the Maretting Manager for Sangamo Electric ompany's Electronic Division.



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